SIXTY-THREE YEARS OF ENGINEERING

FRANCIS FOX

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Maull & Fox.

SIR FRANCIS FOX.

[*Frontispiece*

SIXTY-THREE YEARS OF ENGINEERING

SCIENTIFIC AND SOCIAL WORK

BY SIR FRANCIS FOX

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HON. ASSOCIATE ROYAL INSTITUTE OF BRITISH ARCHITECTS

LONDON

JOHN MURRAY, ALBEMARLE STREET, W.

1924

Printed in Great Britain by
Hazell, Watson & Viney, Ld., London and Aylesbury.

TO

SIR CHARLES FOX

MY FATHER,

AND ALSO TO

SIR DOUGLAS FOX

MY BROTHER

WITH WHOM I WORKED FOR SIXTY YEARS

AND WHO WAS CALLED TO HIS REST ON

NOVEMBER 13, 1921

PREFACE

A word or two seem necessary to explain the arrangement of this book.

It has been difficult to follow any strict chronological sequence. The author's reminiscences group themselves for the most part, and naturally, round the separate enterprises in which he has taken part. Many of these took several years to carry through. He has, therefore, had to choose between a continuous narrative or treating each enterprise or group of enterprises in a separate chapter. Since the interest of the book depends rather on what he has to say about these enterprises than upon the exact sequence of events, he has chosen the latter method.

The book has, for the sake of clearness, been divided into three parts. An Introductory Chapter deals chiefly with the writer's father, Sir Charles Fox, and a few early reminiscences. Part One contains what the author has to say about railways and tunnels. Part Two describes his work in the restoration of ancient buildings. And Part Three is devoted to a number of miscellaneous memories and topics, which could not be grouped under either of the above-named headings.

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CHAPTER I

INTRODUCTORY

SIXTY-THREE years ago I began work with my father, the late Sir Charles Fox, and my brother, the late Sir Douglas Fox.

Of my father I have written in *River, Road, and Rail,* but there are some further facts about him which may be recorded here.

Soon after the opening of the Great Exhibition of 1851, a public dinner was given to him by the Mayor and Corporation of Derby on June 27, 1851. My uncle, Mr. Douglas Fox, who, for three years in succession, held the office of Chief Magistrate of Derby, occupied the Chair, and gave some details about his brother's youth :

" And now allow me to observe that the great and crowning delight of my life was the opportunity afforded of witnessing the well-merited honour done to my beloved brother for his exertions and skill. From his infancy he possessed intuitive mechanical powers, but it has been by his own ability and energy that he has arrived at his greatest measure of success. When he was a child eight years old, if he went into any of the manufactories in Derby, he would return and not only give a faithful description of a machine, but describe with accuracy its mechanical action.

"It was the wish of his father that his mind should be devoted to the medical profession, and he was a student under me until he arrived at the age of twenty; but so inveterately was his mind bent on mechanics that frequently at breakfast his appearance was more like that of a chimney sweep than any decent person" (cheers and laughter) "from his having been plying his favourite studies from early dawn. It was by his assistance that I was able to lay before friends the experiments by which my lectures at the Mechanics' Institution in Derby were illustrated; and I saw that all my hope of my brother becoming a surgeon was gone, and I at once gave him his indentures, and he became a student and eventually an assistant under Mr. Robert Stephenson, under whose fostering care he received a great deal of valuable information."

It was about this date, June 1833, that Dr. Chalmers visited my grandfather's home in Derby. In his diary, published by Dr. Hanna, his son-in-law, he says: "I visited the talented and cultivated family of the Foxes, at the Wardwick in Derby, one of the best and most interesting families I ever knew." This refers to Dr. Francis Fox and Charlotte Fox, my grandfather and grandmother, and their children, Frank, Douglas, Archibald, and Charles, Julia, Harriet, and Charlotte.

In talking about his early life in Derby, my father used to describe the introduction of gas made from coal, the credit of which was due, among others, to Mr. George Low, who fixed the first light over the front door of my grandfather's house in the Wardwick. It was regarded as so extraordinary that crowds of people, passing along the street, stopped to gaze at it with wonder and admiration.

When my father gave up the idea of becoming a surgeon, he left Derby for Liverpool, his entire fortune consisting of eight sovereigns. He obtained work under Ericsson (*River, Road, and Rail,* page 2) ; afterwards with Messrs. Preston & Fawcett, the celebrated makers of machinery, and for a time as engine-driver on the Manchester and Liverpool Railway, at £1 a week. He was present when Mr. Huskisson, a Director of that Company, was killed.

He was eventually articled to Mr. Robert Stephenson and became one of his assistants in the construction of the London and Birmingham Railway (now part of the main line of the L.M. & S.). Whilst thus employed on the London and Birmingham Railway, he received an offer from Captain W. S. Moorsom to act as his assistant on the Birmingham and Gloster Railway with a salary of £750, and was also invited by Mr. Robert Stephenson to go out to Italy to construct the Florence and Leghorn Railway, at a salary of £1,250 a year. Both of these offers he declined, from the conviction that to remain with Mr. Robert Stephenson at the London end of this, the most important line of railway, would not only give him a standing in his profession which he could not hope to attain in any other situation, but would bring him into contact with the many foreign engineers who visited this great work.

He remained with Mr. Stephenson until the railway was completed and opened for traffic, and then, in order to gain a thorough knowledge not only of the construction and repair but also of the working of railways, he applied for and obtained the appointment of Resident Engineer to the London half of the line, at a salary of £300 a year. He had not been long in this position when he received a tempting offer of £1,500 a year to take over the management of a large establishment in London. But this offer, too, he refused for reasons similar to those I have already described. He continued to fill the arduous post of Resident Engineer until the end of 1838, when he tendered his resignation and received an acknowledgment for his services in the form of a cheque for £500.

Before the opening of the Exhibition of 1851 I was taken to Paris by my father and mother. We were accompanied by Mr. Thomas Brassey, Mr. Joseph Paxton, and Mr. John Cochrane, who, with my father, had various important matters of business to which to attend. We went to Versailles to select a number of orange trees, growing in large boxes, for the decoration of the Exhibition, and afterwards of the Crystal Palace. Some of them I believe are still at Sydenham.

Mr. Brassey, the contractor for the Paris and Rouen Railway, asked my father to accompany him to Rouen to inspect the scene of the accident which had just occurred to the great Viaduct on that railway. This was the latest of several unfortunate contretemps which gave rise to the remark that the name of the railway ought to be changed to "Perish and Ruin." On their arrival on the scene they were received by the members of the staff, all of whom were in a state of consternation, as the Viaduct was lying flat on the ground, and they were expecting their dismissal.

Both my father and Mr. Brassey held the opinion that it was a mistake to blame any employé for an accident unless it had occurred through gross carelessness or neglect. If the accident were due to misfortune or to an error of judgment, they considered that the man had been educated at the expense of his employer, and was not likely to repeat the blunder; in fact he would be the safest man to employ at that particular point.

Mr. Brassey looked at the ruins and then remarked, "It's a bad job." My father said, "Well, Brassey, you take it quietly enough! What are you going to do?" "Do!" was the reply, "put it up again of course; it will only alter the figure at the foot of the column in the ledger."

While we were in Paris we visited the studio of the famous photographer M. Daguerre, one of the earliest workers in what was then a new art, who gave his name to the once popular "Daguerreotype." He was the maker of perhaps the earliest form of stereoscope, that ingenious contrivance which enables the object photographed to stand out so wonderfully in relief.

I have a considerable collection of these photographs prepared for the stereoscope, all printed on silver plates.

We stayed at the Hôtel Bristol in the Place Vendôme (looking on to the Rue de la Paix). My father had a suite of apartments in the hotel, as it was very central, and he had to be in close touch with the Emperor Napoleon III and the members of the French Government. Amongst the many important works which he assisted in carrying out, not only in France but elsewhere on the Continent, may be mentioned a portion of the Paris and Marseilles Railway, between Dijon and Tonnerre, with its great number of tunnels; the large bridge over the River Saône at Lyons; the railway from Geneva to Ambérieu; the Berlin waterworks; the harbours at Kiel and Korsöer; the railway from Copenhagen to Korsöer; the drainage of Harlemmer-meer in Holland; and the great bridges over the River Danube at Budapest and over the River Dnieper at Kieff.

It was in 1850 that my father was first asked to interest himself in the building of the Great Exhibition in Hyde Park. The Commissioners had received 240 different designs, but to Mr. (afterwards Sir) Joseph Paxton belongs the credit of the scheme ultimately adopted—a palace of iron and glass with many novel details of design. In like manner it was due to the energy and skill of my father, afterwards Sir Charles Fox, that Paxton's bold project, based upon the Chatsworth conservatory, was translated into accomplished fact.

It should be borne in mind that although the building was intended to last only for two or threeyears, it has stood on its present very elevated site at Sydenham exposed to all the vicissitudes of our climate for seventy years, and is still in such good condition that, with a continuance of the care bestowed upon it by Mr. Wright, the present engineer, it may confidently be relied upon to stand for another long term of years.

In my book, *River, Road, and Rail* (John Murray, 1904), were narrated some of the difficulties which arose in the erection of this unique structure. Some further interesting and amusing facts have come to light, which are worth recording.

The troubles and opposition that were encountered from the first were almost insuperable. One of the first difficulties was to obtain possession of the site in Hyde Park between the Serpentine and the Knightsbridge Barracks. This was effected only on July 30, 1850, ten months prior to the intended opening on May 1, 1851.

The Solicitor to the Treasury gave it as his opinion, that until a Royal Charter was obtained the Commissioners could not legally proceed, and were, therefore, not in a position to give an order to anyone. My father's firm, however, faced the risk of preparing the drawings and making arrangements for the erection of the building without waiting for the grant of the Charter. At the same time they requested the Commissioners to appoint Mr. (afterwards Sir) Joseph Cubitt, the President of the Institution of Civil Engineers, as their representative with whom to consult. It was not until October 31, 1850, that the Charter was obtained, and by this time my father's firm had expended £50,000 without any security from the Commissioners. Lord Granville stated publicly that " but for the courage thus evinced by them, the Exhibition of Industry of all nations would never have taken place."

One of the greatest difficulties was to find a sufficient number of firms of ironfounders to supply the girders and columns, and to ensure that these would fit together exactly when deposited on the site. Standardisation was, therefore, adopted, so that everything should be a multiple of eight, and the bolts and bolt holes should all correspond.

Perhaps one of the most hazardous and certainly the most interesting part of the work was the raising of the sixteen ribs of the transept to their places. A month was the shortest time allowed for this operation, but they were all fixed in eight working days, the last one being put in place in the presence of H.R.H. the Prince Consort.

The question of preserving the large elm trees on the site had to be dealt with, and this was solved in most cases by the introduction of the fine centre transept, referred to later on, instead of the flat roof proposed in Mr. Paxton's original sketch. An immense improvement was thus effected in the appearance of the building. One or two of the trees, however, were in the exact line of the façade of the structure, and their removal was essential. Application was accordingly made to the Office of Woods and Forests for permission to remove them, and the following peremptory reply was received from Lord Seymour (afterwards Duke of Somerset) : " I thought that my former letter had been distinct enough to satisfy you by an explicit answer: I object to any tree being cut."

But an equally high official, Lord Grey, wrote to Lord Granville:

"The Prince is very anxious that the trees which are to come down for the building should be cut at once, before any ill-natured person can move anything about them in the House of Commons. Once down, they will puzzle even Lord Brougham to put them up again. If they could be cut down in the morning and the carcases at once removed, I am sure from experience in such matters they could never be missed. Would it be impossible to get them down to-morrow?"

A meeting was therefore arranged on the spot, when all who were interested attended, but the leading official ordered that "the trees must not be touched." My father turned to his foreman and said, "John, you hear what this gentleman says: on no account must this tree be removed." "All right, sir." That night the Gordian knot was cut; the tree was felled, and, as Lord Grey had said, when once down it could not be reinstated.

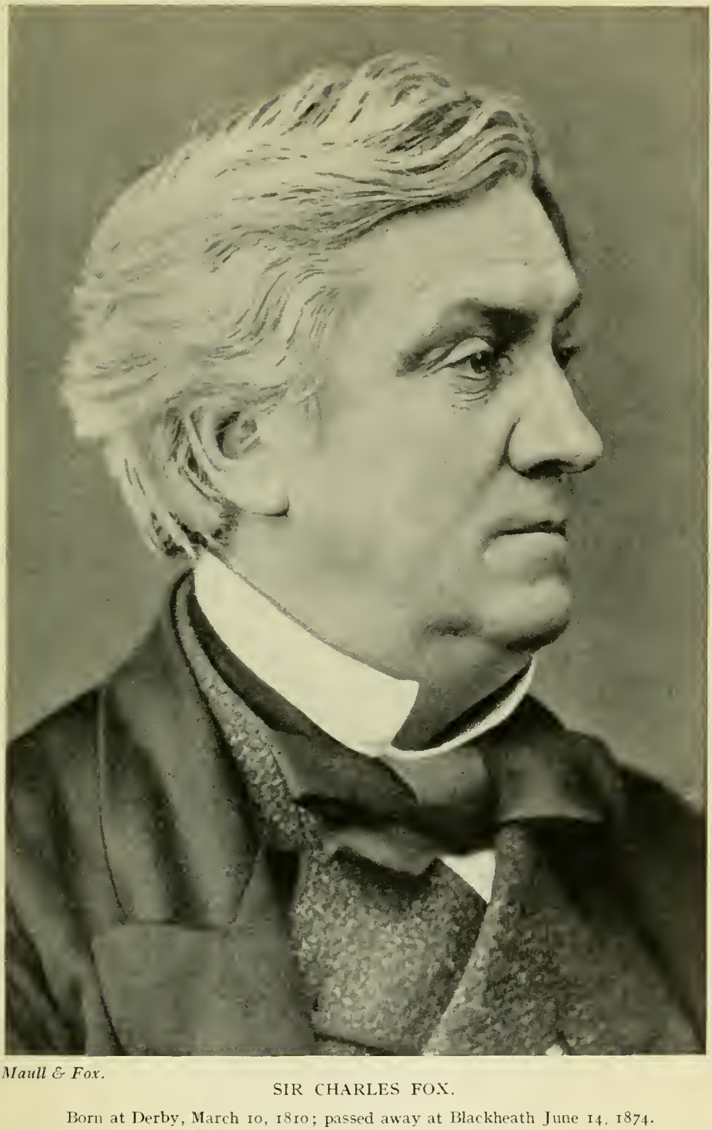
Two thousand three hundred men were employed on the work, besides many thousands of others in the blast furnaces, foundries, and workshops of every kind throughout the kingdom.

The entire building, covering an area of 18 acres, was erected in twenty weeks. The glazing, which ran into many more acres, was executed with great rapidity by means of a large number of tents travelling on wheels which ran in the gutters of the roof. The workmen were thus enabled to fix the glass and putty in the stormiest weather. It is an interesting fact that many of the original sash bars, made of ordinary timber, lasted over sixty years, and were only removed from the building quite recently (1918–20).

The extraordinary speed with which the building was erected went some way to justify the statement of a well-known and competent authority of the day that " England possesses mechanical appliances and physical energies far exceeding those which gave form and being to the most celebrated monuments of antiquity."

At the dinner mentioned on page 1 the guest of the evening gave an amusing list of objections raised by scientific bodies, and men of high position, intending to prove the impossibility of erecting and maintaining such a fabric.

" As the building progressed," said Sir Charles Fox, " I was assailed on all sides, not only by unprofessional persons, but by men of high scientific attainments who doubted the possibility that it could possess, as a whole, that strength which was necessary to make it safe against the many trying influences to which it must be subjected. This opinion was held, notwithstanding the careful calculations which had been made, and the satisfactory proofs to which all the important parts were individually subjected, as soon as these parts were put together, thus producing a structure of unparalleled lightness. One gentleman, after complimenting me on the beautiful appearance of the building, stated his belief that it would never come down unless it



Maull & Fox.

SIR CHARLES FOX.

Born at Derby, March 10, 1810; passed away at Blackheath June 14, 1874.

tumbled down, hinting that the first gust of wind would blow it down like a pack of cards. Another, holding a high scientific appointment under Government, after a long investigation of the various parts of the building, expressed at the Institution of Civil Engineers a belief in the entire absence of safety in its construction ; and after explaining the mode of connecting the girders with the columns by means of projections technically called ' snugs,' went on to indulge in an *airy* [1] prophecy that ' a wind exerting a force equal to 10 lb. per superficial foot would bring such a strain upon these snugs as to break them all off, and cause them to fall down in showers.' I may just remark that since the expression of this opinion the wind gauges around London have registered in the late storms upwards of 20 lb. per foot : and I have pleasure in informing you that the encouraging predictions of this gentleman as well as those of many others have not yet been fulfilled."

" It may be amusing and not uninteresting to enumerate briefly some of the difficulties and dangers which were foretold :

" 1. We should never get through our work in time.

" 2. The foundations were defective, and would surely give way.

" 3. The building was more like scaffolding than anything else, and was so light that it must tumble down.

" 4. The weight of the goods and people in the galleries would be sure to bring down the building ; and if the mere weight did not produce the effect, the vibration caused by people walking, or more especially running, would be sure to do so.

[1] This refers to *Punch's* amusing remark that the Astronomer Royal, Professor AIRY, should have been Professor WINDY.

"5. The girders, expanding by the heat of the sun, would push the columns out of their places, and in so doing would break them, and let down the building.

"6. That if it should happen that the weight and vibration did not produce the effects expected, the equinoctial gales would at all events finish the business.

"7. That if the building was not blown down, the sashes or windows were so feeble that they would assuredly be blown in or out, but it was difficult to say which.

"8. That the glass was so weak that it could not resist a gale of wind, but would inevitably be blown to pieces.

"9. That if the wind did not act as was expected, firing cannon in Hyde Park on the opposite side of the Serpentine could not fail to demolish the windows.

"10. That the first hailstorm would leave the whole roof without glass.

"11. That by the vibration of the moving machinery the building would be gradually shaken loose in all its connections, and must consequently fall down.

"12. Such were the fears entertained for the safety of the galleries containing the large organ and choirs, that a request was made to Dr. Henry Wylde by some members of the Jury for musical instruments that he would, previous to the inauguration, urge upon my mind the necessity for an investigation into the results likely to ensue from the effect of the vibration which would be brought into action during the performance of the National Anthem.

"13. That the vibration caused by the diapason pipes of the large organ would shake out the glass, which would fall in showers upon the spectators; and our Chairman was accordingly instructed by the Commissioners to make experiments with the view of ascertaining what the result would be—and these experiments were officially made on the day previous to the opening.

"Many of these misgivings appeared in the newspapers and one foretold that we were on the eve of a frightful catastrophe, but wisely abstained from pointing out the nature of the danger we were running. In fact, statements of this kind were so frequent and pointed, that we were often seriously advised to reply to them, but feeling confident we were right, and that we should succeed in all that we have undertaken, and consequently that the more people spoke against us, the more complete would be the reaction in our favour, we abstained from taking any notice of what was said, leaving the public to amuse themselves in the matter in any way they thought proper."

I was only seven years old when the Exhibition was opened, but I used to visit the building with my brother Douglas during its erection nearly every day, and on several occasions with the old Duke of Wellington. He was almost the only man who thought the work would be completed in time, and he used to pat my father on the shoulder, saying, "You'll do it yet." On one of these occasions my father was called away, and he requested the Duke "to look after my boys that they do not get into danger from the machinery." His Grace took my brother Henry and myself both by the hand, and we found it impossible to release ourselves from his iron grip. We felt, in later years, that we understood how he won the battle of Waterloo, and earned the title of "The Iron Duke."

A pleasing incident occurred on the opening day. The Duke was an early arrival, and he walked up to my father and, grasping his hand in both of his, said, "Didn't I say you would have it ready in time?" As a marvel of rapid work it has never been equalled either before or since.

The following letter was written by Queen Victoria to her uncle the King of the Belgians two days after the opening of the Exhibition:

Buckingham Palace,
3rd May 1851.

My dearest Uncle,

I wish you could have witnessed the 1st May 1851, the *greatest* day in our history, the most *beautiful*, and *imposing* and *touching* spectacle ever seen, and the triumph of my beloved Albert. Truly it was astonishing, a fairy scene. Many cried, and all felt touched and impressed with devotional feelings. It was the happiest, proudest day in my life and I can think of nothing else. . . . The triumph is *immense*, for up to the *last hour*, the difficulties, the opposition, and the ill-natured attempts to annoy and frighten, of a certain set of fashionables and Protectionists, were immense: but Albert's patience, firmness, and energy surmounted all, and the feeling is universal. *You* will be astounded at this great work, when you see it!—the beauty of the building, and the vastness of it all. I can never thank God enough. I feel so happy, so proud. Our dear guests were much pleased and impressed. . . .

Now good-bye, dearest Uncle,

Ever your devoted Niece,

Victoria R.

Before describing the circumstances which led to my own entry upon engineering work in 1861, I may perhaps be allowed a few varied recollections mainly concerned with London, of a time now long past.

One of the greatest attractions in London in those days was the entertainment by Albert Smith depicting the ascent of Mont Blanc, with his inimitable description of Switzerland and of the Swiss, who, at that date, were but little known to the public.

The Diorama or Panorama in Regent's Park, on the site of which the Baptist Church of the Rev. W. Landels was built at a later date, was also very interesting. We were ushered into a dimly lighted passage, draped with heavy dark-red velvet curtains, leading into what was apparently a small chamber equally sombre, and called "the ascending room"—the first attempt, it is believed, at achieving the modern lift, or elevator. The doors were closed; we were conscious of the working of some machinery, and also of some kind of mysterious movement; and when this ceased and the doors opened, we found ourselves on a circular gallery at a considerable altitude. In front of us was a life-like representation of the "great earthquake of Lisbon" with the accompanying noise and crash of falling buildings.

On other occasions was shown "London by day," followed by "London by night"—spectacles which lived long in the memories of those who saw them.

"The Polytechnic" in Regent Street, since remodelled by Mr. Hogg, was a most excellent and instructive institution, under the control of the well-known scientist Professor Pepper, of "Pepper's Ghost" fame, assisted by Mr. King, who lived at Merton.

One of the great features of the Polytechnic was a daily lecture by Mr. King, illustrated by lantern slides, on any event that had just occurred, sometimes only the day before, in distant countries. In after years Mr. King told me of the immense amount of research (undertaken in the shortest space of time) that these demonstrations demanded, adding that "although there was on the Throne our beloved Queen Victoria, there was only one *King*." The old diving-bell and diver, announced by the loud gong of unusual power; the glass blowing; and many other highly instructive demonstrations filled every moment of one's time on these visits.

Professor Faraday's Christmas lectures at the Royal Institution were great events in our lives as children. His simple experiments and explanations were a never-failing source of pleasure; and if an experiment did not always succeed, we were intensely delighted with his investigation into the cause of the failure, and appreciated his kind and sympathetic treatment of the assistant, who was never blamed for carelessness in the arrangement of the apparatus.

Professor Faraday after his lectures sometimes came to our house in Portland Place. When the meal was over he would play "hide and seek" behind the furniture of the three drawing-rooms, and often pursue us children on his hands and feet in the rôle of a bear.

During the Crimean War, about 1855, Lord Dundonald proposed a method for capturing, at a cost of a million sterling, the great fortress of Kronstadt, protecting St. Petersburg—or Petrograd as it is now known. By an arrangement with the Admiralty, he had to divulge his scheme to my father, under an oath of secrecy. I have a copy of my father's report, in which he stated his opinion, without giving any details, that the project would be successful.

But although the declaration of peace rendered its application unnecessary, my father would never give us the slightest idea of what had been proposed. All we did know, and that was a matter of common knowledge, was that a mysterious vessel had been built by Scott Russell in his shipyard at Millwall for travelling under water. I remember seeing this, the first of submarines, lying on the banks of the Thames, resembling a Thames barge turned upside down. Alongside of her the *Great Eastern* steamship was then being slowly launched sideways from the same yard. This submarine had been sent into the English Channel and was there cruising about, when one day, coming up to "breathe," she bumped against the keel of a sailing collier, and dented some of her own plates. She was compelled to return to Millwall for repairs, and there we frequently saw her, lying on the muddy banks.

About the year 1861, as a young man of seventeen, I accompanied Lord Clyde to Shoeburyness to witness the testing, for the first time, of the *Warrior* target. This vessel, H.M. iron-plated steam frigate of 6,170 tons, was at that date the largest vessel afloat, with the exception of the *Great Eastern*, and was coated with armour $4\frac{1}{2}$ inches thick. The experiments were not only to test the resisting power of this armour, but also the penetrating effect of a flat-ended shell having neither percussion cap nor fuse, and depending entirely on the heat generated by the impact against the iron plate to explode the charge, which was contained in a flannel bag in the shell. The great object was to have a missile which would deliver the blow as a solid shot, and would not explode until after the perforation of the plate. This would then blow to pieces the heavy oak backing, which was several feet in thickness.

When all was ready the visitors were ordered into shelter, but with the enterprise and curiosity of youth I looked round the corner to observe the result, and was rewarded by seeing the enormously high flame generated by the impact. Investigation showed that a clean hole had been punched through the plate, and the strong oak backing blown into matchwood. The effect of such a missile striking a ship of that period can be better imagined than described.

On our return to London, Lord Clyde was very silent and depressed. He told me he was wondering whether the wars of the future would not bring developments against which man would be unable to stand.

Further recollections bring to my mind the construction of the Victoria Embankment between Westminster and Blackfriars which replaced the mud banks of the Thames. In the old days a large number of penny, and even halfpenny steamers plied up and down the river, and these had to be reached by floating gangways across the mud at low water. Mud banks also extended all along the river in front of the Houses of Parliament. The available waterway was much improved by the removal of the old masonry bridge now replaced by the modern (and none too strong) Westminster Bridge.

Early in the "sixties," when, of course, all vehicles on the public roads were drawn by horses, one's sympathy was often aroused on behalf of these poor animals. They suffered grievously when descending the declivities so often encountered in London thoroughfares; such, for instance, as the incline from the Strand to Whitehall, which exists to-day, and the steep gradients of Holborn and Newgate Street before Holborn Viaduct was built.

Brakes were seldom provided, and the wretched animals in their efforts to retard the heavily laden vehicles, would slide down the hill on their haunches. On the up journey their sufferings were painful to witness. In 1870 I wrote to the Omnibus Company suggesting the provision of brakes, but getting no satisfactory reply, I purchased the necessary shares to enable me to attend the Company's annual meeting, and speak publicly on the subject. It was not only the treatment of the horses, but also the hard lot of the drivers and conductors to which I wished to draw attention, in those days now happily past. Year in, and year out, these men were kept at work for sixteen hours a day and more—Sundays included, for they never had a Sunday's rest unless they paid for a substitute. If a man applied too frequently for a Sunday off, he was dismissed. Men with families scarcely ever saw their children, except when they were abed and asleep.

I attended a meeting and spoke on both subjects, but met with much opposition. The manager objected that the cost of brakes would be prohibitive. As for the men, if they were dissatisfied they could leave. For every vacancy, he said, there would be at least 800 applications.

I declined to accept these statements. I pointed out that if brakes were adopted, the harness could be greatly simplified and reduced in weight, the breeching, the saddle, and the crupper could be dispensed with, and only the bridle, collar, and traces need be retained. I had taken the precaution of getting a design for the brakes, together with a definite offer from a well-known omnibus builder, to supply and attach a suitable brake for £5 a vehicle. I showed that the saving in horseflesh and harness would soon defray the entire expense. As regarded the men, I appealed to the chairman and directors to deal humanely with them, with kindness and consideration.

The chairman replied that my proposals were absurd, and as the manager was determined not to adopt my suggestion, I, being a young man and not anxious for notoriety, left the room in disgust, sold my shares, and severed my connection with the Company.

My protest, however, had not been in vain, for, within a few months, brakes began to be fitted, the harness was simplified, and in a comparatively short time there was not a brakeless bus in London. The men too had their hours of work materially reduced, and in other ways they were better treated.

It had been my father's intention to send Douglas and myself to Cambridge, and my name was actually entered at Trinity College, when an unfortunate and very serious accident befell my father, upsetting all his plans for our future, and changing the whole course of our careers. It happened at one of our seaside watering-places, where the tide, one night, washed away part of the esplanade, leaving a yawning crevasse in the footway which was invisible in the darkness. Approaching the spot during the evening, my father stepped unconsciously into the gap and fell a considerable depth on to the fractured masses of masonry and concrete. Being a powerful swimmer, he would probably have escaped unhurt, had it been high tide; but the water was low and he was very badly injured and rendered unconscious by the fall. He recovered consciousness to find himself lying on a table at the police-station, a passing constable having heard his groans and procured assistance to convey him there. My father survived the accident some thirteen years, but never completely recovered from its effects. Its immediate result was the cancellation of the Cambridge arrangements, and my brother and myself were compelled to plunge into work forthwith.

I was conscious of the fact that my education was arrested, and determined, as far as possible, to make up the deficiency by private study, and by attending the lectures of Professor Tyndall, Dr. Miller, and other leading men of that day. With these studies were combined work in mechanical shops where could be learnt the use of tools, in turning, pattern making, smithing and forging, besides civil and mechanical engineering; and lastly chemistry under my old and valued friend, the late Dr. Stead, F.R.S., of Middlesbrough. Both my brother and I were, about the years 1867–70, officers in the London Rifle Brigade, which, years later in the Great War, did such magnificent work for the Empire.

Our firm, under the title of "Sir Charles Fox & Sons," consisted of my father, my brother Douglas, and myself; but eventually after many years it was changed to its present firm, "Sir Douglas Fox and Partners," to enable the younger generation to be admitted as partners.

PART I

RAILWAYS AND TUNNELS

CHAPTER II

THE VICTORIA BRIDGE, PIMLICO (1864–1867)

Passengers travelling to or from Victoria Station may or may not be conscious of the fact that within a mile of that terminus the railway crosses the River Thames by an iron bridge. This was originally designed by and built under the superintendence of Sir John Fowler in 1859–60 and is one of the handsomest of London Bridges. But as its entire width was only 32 ft., providing for only two pairs of rails, it soon became evident that the great and rapidly increasing traffic would have to be accommodated by a considerable increase in width and in the number of lines. The system of railways designed by my father, Sir Charles Fox, in 1862 not only provided for such a development, but also, by avoiding sharp curves and steep gradients, greatly improved the approach by railway to Victoria Station. From their commencement in May 1864 to the day of the opening, the operations occupied three years. This was the first large project on which I was engaged as assistant to Mr. Edmund Wragge, the Resident Engineer on Sir Charles Fox's staff. The contractors were Messrs. De Bergue, the large firm of bridge builders.

There are great differences between the original and the additional bridges. Both had to conform to the same conditions of span and height above the Thames. Both rest upon four fine segmental arches of 175 ft. clear span with a height of 17 ft. 6 in. or one-tenth of the span. But in designing the new bridge, Sir Charles decided that as the expansion joints were evidently not necessary, he would make no provision for expansion. He had by numerous experiments ascertained that the variations in the length of a wrought iron girder, due to alternations of temperature in this climate, could be accommodated within the limit of elasticity of the girder itself, by variations in the other dimensions. He decided that the total length of 900 ft. should be one continuous girder held rigidly in place by solid abutments at the extreme ends. The girder therefore could not expand horizontally, but could adapt itself to variations in temperature by a slight increase in width or depth.

Few people, who are not engineers, realise how considerable the expansion of metal can be. On the main lines of the railways in Great Britain, the rails have now a length of 60 ft., and this necessitates an increased gap between rail and rail. On the London and North-Western Railway the platelayers are provided with a thermometer fixed in a small portion of rail, on which is indicated not only the temperature of the steel, but also the width of the gap required; on a hot day, when the length of rail is increased, the space may be as little as $\frac{3}{32}$ in., whereas on a cold day, when the thermometer indicates say Zero°, and the rails are contracted in length, the gap has to be $\frac{5}{8}$ in.

To illustrate this in a somewhat forcible manner let us try to imagine that all the rails between London and Carlisle were laid touching one another, without any gap, and also that the whole length of rails was anchored immovably at Euston, but was capable of moving freely in the direction of Carlisle, we should then see the end of the rails travelling beyond Carlisle under the action of a hot sun for no less a distance than 461 yards or over a quarter of a mile, and again receding towards London under the influence of a very cold winter's night a similar distance.

To return to the bridge, one of the most difficult but also one of the most interesting things we had to do was to set out the exact length of the spans or openings across the river. We had to do this, high above low-water level, with accurately marked rods 20 ft. in length, on a single baulk [1] of timber 12 in. in width, on which was fixed one of the iron rails for moving forward travelling cranes. There was therefore no hand-rail, and only just 5 inches width on each side for foothold at a height of 50 ft. above the water. With passing steamers and barges it was difficult enough to keep one's head and maintain one's balance ; but the danger was increased because each of us at the end of the 20-ft. rod had to kneel down on the baulk, make the necessary

[1] The baulk is the beam, which lies right across the river, on which the travelling cranes run.

mark, then get up and repeat the operation at each length of the rod, all the way across.

At a certain distance, farther along the railway towards Clapham Junction, a bridge with 120-ton girders had to be provided for carrying the new viaduct across the London and South-Western Railway, and three other main lines. To avoid the inconvenience as well as the danger of erecting this bridge *in situ*, it was decided to build each girder on the adjacent viaduct. When it was ready to be placed in position, all the necessary arrangements having been made, we were to begin the operation of rolling it forward at midnight, and to complete it by 4 a.m. during a four-hour interval between trains. In order to do this, traffic was stopped on two out of the four pairs of rails above which the girder had to be placed in position. As the interlocking of points and signals had not at that date been invented, my brother Douglas and I went to the points of junction some 500 yards distant from the viaduct and drove in solid wedges, to prevent the rails being moved and to ensure the trains running on the right line. At 12.10 a.m. we heard the whistle of the last train leaving Victoria, and signals by hand lamps were made to the driver that he might pass, when to our great alarm we found that the train was on the wrong line and was going direct into the heavy timber lorry on which the projecting end of the girder was being carried. Someone had gone to the wood blocks, had taken them out, and had wedged the points exactly the wrong way. Fortunately the driver was on the alert, and he was able to see even in the midnight darkness that he was going direct into the lorry. He at once applied his brakes, reversed the engine, and brought the train to rest within 10 ft. of the obstruction. Had he failed in doing this he would have knocked the lorry from under the 120-ton girder and have brought the latter on the top of the engine and train. Needless to say the driver was thanked and suitably rewarded on the spot, for his vigilance and promptitude. It was another proof of the care of those splendid men into whose hands passengers place their lives without hesitation and even without thought, every time they take a journey.

CHAPTER III

THE MERSEY TUNNEL AT LIVERPOOL (1880–1886)

THIS great work has been described so often and in such detail that I shall confine myself to relating certain interesting details and incidents which have not hitherto been made public. It may be recalled that the construction of the tunnel was undertaken by Major Isaacs in 1880, and the railway was opened for traffic in 1886 by the late King Edward when Prince of Wales. The engineers were my brother Sir Douglas Fox, Sir James Brunlees, and myself. Mr. Archibald H. Irvine was the Resident Engineer, and Mr. John Waddell the contractor. The length of tunnel actually under the Mersey is 1,320 yards, between the pumping shafts in Liverpool on the east bank and Birkenhead on the west 1,770 yards. We began by sinking the two shafts, and equipping them with ample pumping power to deal with the maximum quantity of water. The shafts were 15 ft. in diameter and 170 ft. deep, and where they passed through the beds and fissures of the New Red Sandstone they were very wet.

I should like at this point to refer to my old friend Mr. Mellard Reade, the well-known geologist of the date mentioned above.

Soon after the commencement of the work he called upon me in Liverpool and wished to speak to me in confidence. He, as a consequence of his researches, had located the position of the old bed of the River Mersey in geological ages; and he predicted that the excavation for the tunnel would pass through the old bed or ravine, and that we must be prepared for difficulty at that point (see section). He was desirous not to raise any doubts as to our ability of getting safely through.

In the course of the work we did encounter the old bed, and made such preparations as enabled the tunnel to be carried through safely—but it was a remarkable verification of his opinion—and a loyal act on his part to warn me beforehand. The rough section shows how the strata dip from west to east; the dip is exaggerated, represented by the sloping irregular lines in the diagram. As the shaft descended we cut these beds in succession, and they yielded large volumes of fresh water, not salt, these fissures cropping out inland.

The actual tunnel was not to be excavated until a drainage heading had been driven some considerable distance to test the strata under the river. This drainage heading was made on a rising gradient of 1 in 500 to enable the water to flow down it to the sump at the bottom of the shaft. As the drift went forward, the volume of water increased so rapidly that it became a serious question whether we should ever get through. When the heading penetrated the fissure at *a* the water which was coming into the shaft at *a′* in mining language "took off," and flowed into the shaft at *a*: in like manner the water which flowed in at *b′* ran into the heading at *b*.

Some friends of ours paying a visit to the works found Irvine and myself sitting under a large umbrella hung from the roof of the driftway and calculating whether, if the same ratio of increase in volume continued in proportion to the distance driven, we should be able to get through. We were at that time under the land, and were encountering only fresh water. What would it be when we were under the river and had the

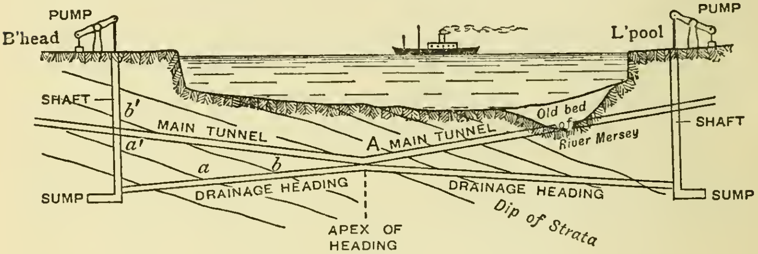


FIG. 1

salt water to deal with in addition? We came to the conclusion that if the water increased every 100 feet as it had done in the last 100 feet, no pumping power could grapple with it. But fortunately, on reaching the point marked A where we cut the first bed which cropped out into the river, and where we feared we might get salt water direct from the Mersey, we encountered very little. We found that in course of ages the river had practically filled all the fissures with clay, which had become indurated and water-tight. This was fortunate, indeed, for the roof of the heading was so badly fissured that it had

Swaine & Son.

SIR DOUGLAS FOX.

Born, May 14, 1840; called Home, November 13, 1921.

very much the appearance of a jig-saw puzzle. One of the fissures was 10 in. wide for the whole width of tunnel.

From this point forward the ratio of increase rapidly diminished although the rock roof of the tunnel was fissured in all directions, and some of the cracks or veins were as much as 11 in. in width. At one period we had to pump from 8,000 to 9,000 gallons per minute, and at the date of opening it was still 7,000 gallons.

But there was another uncertainty hanging over us: would the feeders of water, entering the tunnel through the red sandstone rock, gradually erode it away, and so increase the flow? Or would the fissures gradually silt up, and thus reduce the volume to be pumped?

It was very satisfactory to find that the inflow of water, which in 1886 was 7,000 gallons per minute, had by 1919 diminished to 6,000 gallons.

As the Drainage Heading continued on a rising gradient of 1 in 500 towards the centre of the river, to meet a corresponding Drainage Heading from Liverpool, I arranged for a "rapper wire" or electric bell to be fixed, by means of which the engine-man at the pumping engines could give warning to the miners at *a* should anything go wrong. Unfortunately this was allowed to go out of action, with the result that the water in the shaft rose within a foot or so of the roof of the Water Level at its entrance, before the miners at *a* became aware of their danger by finding water at their feet. They made a hasty retreat, and before they reached the shaft they were up to their necks in water; had they been ten minutes later they would have been cut off. I gave orders at once for a small "staple" shaft to be made at *b* into the main tunnel, as soon as it had reached this point, so as to prevent the possibility of such an accident in the future.

The drainage arrangements have proved very efficient and have resulted in the tunnel itself being remarkably dry. On the occasion of the opening by the Prince of Wales the tunnel was lighted by gas, and thousands of visitors walked through from end to end, without seeing a drop of water. Their only complaint was that it was slightly dusty!

I adopted the practice of visiting the works frequently at 3 o'clock in the morning, in order to encourage the men in their wet, dark, and hazardous operations, as I knew that about that time they would be getting tired, and perhaps disheartened. The following incident will show what absolute confidence the miners placed in the engineers and inspectors. It was necessary to be certain as to the thickness of the rock which intervened over our heads, between us and the water in the river. I therefore applied to the authorities for permission to bore a vertical hole 2 in. in diameter, upwards from the heading to the bed of the river. If by ill-luck we found that the tool entered the river, we were provided with a long plug of durable timber, about 15 ft. in length, which could be driven into the hole to plug off the water.

The request was refused and I was politely told it would be " the act of a madman and must not be done." The men, however, were in a state of nervous fear lest in blasting they should blow a large hole in the river bed, when we should have had " Mersey upon us." I therefore undertook the responsibility of having several holes bored upwards. In no case did they extend to a greater height than 15 ft., as I knew that if we had as much solid rock as that above us the work, and consequently the men (and as a matter of fact *ourselves* also) were safe, and that so soon as the thick brick arch of the tunnel was completed, the work would be sufficient for all time. But the operation was kept secret for fear it might be stopped, and in no instance did the tool enter the river.

Some years later I was talking to one of the two men who were working in the far end, and he said to me :

" We were working at the far end of the drainage heading and you coomed along one morning about 3 o'clock and we was gettin' tired and lonesome-like, and I says to you, ' Mr. Fox, how much rock have we over our heads ? ' You said, ' Fifteen feet.' And I says to you, ' That's all right,' and you said ' Good-bye.' My mate says to me, ' How the dickens does he know that ? ' and I says to him, ' Oh, he knows everything.' "

On another occasion, in the early morning, a huge piece of rock dislodged by the excavators who were at work at the roof of the tunnel fell into a large pool of water, crushing some timbers and sending the water in all directions. It scared the men close at hand, and they foolishly shouted "The river's in." Immediately the other men became panic-stricken and rushed towards the shaft shouting out the same words. Many were knocked over, lights were extinguished and men fell over tubs and wagons, bricks and timber in their mad career. Fortunately they met an inspector, one of the most valuable members of our staff, named—inappropriately enough—Mr. Fright. Fright, cool and collected, asked from what they were running. "Oh!" they replied, "the river's in." "We'll go back and see whether it is," he said, and this stopped the panic.

Another accident ended more seriously. At Liverpool, at 4 o'clock one morning, when the "shifts" were changing, some young miners in the shaft cage, eight in number, who were descending the shaft began "sky-larking." When the cage was about half-way down, one of them let his petroleum lamp project beyond the end of the cage. The lamp was caught by the shaft timbers and upset, with the result that the petroleum flowed all over the bottom of the cage, and there was immediately a bonfire with the eight men in it. Hearing the noise and cries of the men, the engine-man at "bank" stopped the cage, which was consequently suspended half-way down the shaft. Two of the men jumped out and, falling to the bottom, were instantly killed, two others climbed up the wire rope to get out of the flames, and the other four were badly burnt.

The excavation of the heading through Sandstone Rock was effected from the Liverpool shaft by hand labour with drills and explosives, advancing only 9 yards per week of six days, whereas from the Birkenhead side a powerful boring machine invented by Colonel Beaumont, R.E., was employed. This made rapid progress, as much as 34 to 65 yards in a week. But in the end, owing to breakdowns, and delays from various causes, it was found that when the headings met, the average weekly advance from both sides was precisely the same—viz. 9 yards per week.

The accuracy with which the heading was driven reflected the greatest credit upon the Resident Engineer Mr. Irvine, and upon the Contracting Engineer Mr. Davidson. The total error was only one inch.

The arrangements for ventilation in the finished tunnel had to be very complete, owing to the fact that in its early days the railway was worked by steam locomotives. Over a million cubic feet of air per minute was ejected from the tunnel by means of powerful fans 30 ft. and 40 ft. in diameter ; consequently an equivalent volume of fresh air flowed in. Electrical working was afterwards introduced, and all products of combustion avoided. This enabled most of the fans to be removed, and the air of the tunnel greatly improved, whilst the annual cost of ventilation was reduced from £5,430 under steam to £332 under electricity.

The increase in traffic since electrical working was introduced has been remarkable. In 1902, which was the last year in which steam trains ran, the number of passengers was under 7 millions, whereas in 1913, the last year for which figures are available, it was 16½ millions.

During the construction of the tunnel, the British Fleet arrived off Liverpool and unwittingly anchored almost immediately over the tunnel, near the landing stage, in 100 ft. of water. It was dusk and very soon became quite dark. About 2 o'clock in the morning the ships were shaken by some explosion which the Admiral thought was a torpedo, or mine, and which, he said, produced a sensation as if his ship had been lifted three feet out of the water. The crews were called to quarters, all the flood and watertight doors were closed, and a minute examination was made of every part of each ship. No damage was discovered, and the cause remained a mystery, until the morning. The Admiral then learned that it was due to shots fired in the blasting operations beneath the bed of the Mersey, operations which we had carried on in all innocence.

CHAPTER IV

MANCHESTER, SHEFFIELD AND LINCOLNSHIRE RAILWAY; AFTERWARDS, THE GREAT CENTRAL RAILWAY (1882–1899)

On August 15, 1882, I received a letter requesting me to call upon the Chairman of the Manchester, Sheffield and Lincolnshire Railway Company the following morning. I had not previously met him personally and had no idea for what purpose I was to see him. I called punctually to the minute, and was shown into his large room. At first I could see no one, but heard the rustle of papers on a desk, and then found myself in his presence.

He at once began: "I want you to build a railway; there are the plans" (pointing to a large roll). "Take them away, and don't let me see them again until the railway is ready for opening."

I was somewhat surprised at his abruptness and quietly said: "I am much obliged to you, sir, but I should like to ask you two questions. Have you not already an engineer in London? I should not wish to take work out of the hands of a brother engineer."

"To whom do you refer?"

"Mr. A.," I replied.

"Oh, he is not going to do it."

Then I asked if there wasn't another engineer in the north who would naturally expect the work.

"You refer to Mr. C. Well, we don't intend to entrust the work to him. If you don't wish to have the work, leave it alone: but if you are willing to act, there are the plans. Take them away, and as I said just now, don't let me see them again until the work is complete."

I thanked him, and again explained that our rule in business life was never to take work from our brother engineers unless there was full justification.

Thus began my career in the Company's service, which lasted some twenty years and brought me into close and pleasant intercourse with many of the leading men of the Empire.

One of the first works which came under my care was the proposed swing-bridge over the River Dee a few miles below Chester. A prolonged and costly investigation before Committees of the House of Lords and House of Commons resulted in the Bill being passed, and within a few days I was asked by the Company as their engineer to prepare the necessary designs and contracts for the work.

Knowing that Mr. James Abernethy had acted for them, I called upon that gentleman to acquaint him with the situation. He said that naturally he would have been glad to execute such an important work, as it would be the largest opening span—140 ft. clear in width—in the United Kingdom, but that, as he had already been paid for his services up to the grant of the necessary power, I was quite at liberty to act. He thanked me for calling upon him, and on parting wished me "good luck."

In the construction of the bridge I collaborated with our late partner, Mr. G. A. Hobson, and with Mr. Ralph Freeman. There were several points of great difficulty. Economy in design and construction was essential, and at the outset we were met with the fact that the river presented no solid foundation. A boring had been put down over 100 ft., and nothing more solid than quicksand was found on which to base the bridge.

The well-known song beginning "Mary, call the cattle home," refers to these treacherous sands of Dee. To this day if a vessel gets stranded on the sandbanks by the falling tide, the first thing the skipper does is to send his crew to their berths so that nothing should move or vibrate on board and thus tend to sink the vessel into the silt, until the rising tide floats her off.

However, we found a means to provide the bridge with a firm support, namely, a cylinder, consisting of a circular wall of brickwork-in-cement, 43 ft. in diameter, 5 ft. thick, with a steel cutting edge at the bottom. This was lowered on to the bed of the river, but we were immediately faced by a prospect of disaster.

A serious flood occurred in the river, and the whole thing tilted over some 5 ft. The chairman of the Company unfortunately visited the work the next morning. He was much disconcerted, and expressed the opinion that we could never recover it, and that it was, in fact, lost. I asked him to come again in two or three weeks and meanwhile not to be uneasy, as I knew a method by which it could easily be rectified.

An iron pipe 2 in. in diameter, with a nozzle at the end, was lowered into the bed of the river close to the obstruction, the pipe being attached by a hose to a powerful steam pump. The water issuing from the jet rendered the silt or sand "quick" beneath the obstruction, which rapidly sank away and the cylinder righted itself. By means of this water-jet the cylinder of brick-work, weighing 2,500 tons, which had canted over to such an extent as to cause dismay to many besides the chairman, was brought back into position within three-quarters of an inch of its desired place in a few hours. In fact, it was possible to play with this great mass, and move it one way or the other exactly as one wished.

The water-jet is also of the greatest value in sinking timber or iron piles for bridges or pier foundations. To drive piles into sand requires very heavy blows, and the sand soon becomes, by impact, as hard as rock, and the piles receive injury; but by the water-jet they can be sunk to 25 to 30 ft. in two or three minutes, and they can be moved in any direction required, so long as pumping is continued; when this ceases the sand in a few minutes settles round the pile and grips it tightly. By adopting this process it is unnecessary to point or shoe the piles; they can be cut off square to begin with, and it need not be said that, for stability and security, a square ended pile is far better than one that is pointed.

On a section of the railway near Birkenhead, Mr. Gladstone had kindly consented to cut the first sod, for which purpose a dais was erected some 7 ft. in height, with a wooden screen at the back to keep off the wind, and the whole structure was covered with bunting. A considerable gathering was anticipated, possibly some 4,000 people, and the necessary area for cutting the sod was roped off to enable the crowd to hear Mr. Gladstone speak. A body of police to keep the ground were present, and as Fenianism was then rife, a number of private detectives were also in attendance. But before the ceremony began some 40,000 people had collected. Very soon the ropes were trodden down and the vast crowd surged right up to the dais, even to the small flight of steps down which Mr. Gladstone and the other speakers were to descend on to the turf. We were afraid that the ceremony would have to be abandoned, but Mr. Gladstone refused to alter the arrangements and boldly plunged into the crowd. It reminded one of an observatory beehive, for wherever we on the platform saw the crowd forming a concentric circle we knew Mr. Gladstone must be in its centre.

A silver shovel with which to cut the sod had been handed to Mr. Gladstone, but this promptly buckled up when forced into the turf, and I heard him say "Give me a proper spade." A spade was found, and the sod duly cut by the great man.

But now a fresh difficulty presented itself. How were we to get Mr. and Mrs. Gladstone away without passing through the crowd ? I hit on the idea of placing a chair and a table against the screen ; at the back, on the table, another chair, from which we were able to lift Mrs. Gladstone over the screen and lower her direct into their landau carriage. Mr. Gladstone followed, and the carriage drove safely away. I am bound to say I did not myself attach much importance to the episode until, after their departure, I was warmly thanked by the leading detective ! Twenty years later I met Mrs. Gladstone at Downing Street, and without reminding her of this incident I said that she had no doubt forgotten me. "Forgotten you !" she replied, "Mr. Fox, never ! you saved our lives at Birkenhead."

Great Central Railway

In 1894 (the Manchester, Sheffield and Lincolnshire Railway having by that date become known as the Great Central Railway) I was summoned to Manchester by the late Lord Wharncliffe, who had just been elected chairman of the Company. He instructed me to take in hand that portion of their extension to London which lay between Rugby and London.

So soon as the necessary land, generally old pasture land, was acquired, it was fenced in to prevent trespass. The turf and top mould were stripped off to provide soil for the slopes of the embankments and cuttings. In this operation the subsoil, which had not seen daylight possibly for centuries, was exposed, with a very remarkable result. During the ensuing summer practically the whole length of the railway became a magnificent belt of bright scarlet, owing to a thick growth of millions of common red poppies (*Papaver Rhœas vulgaris*), which are not naturally common in the district. From any high hill it looked as if a brilliant scarlet ribbon were stretched to indicate the site of the new but temporary extension of the Diocese of Peterborough.[1]

The same phenomenon has been observed elsewhere when pasture land is stripped. The only explanation I can offer is that the seed must have been lying dormant in the subsoil.

The Rev. W. Wilks, of Shirley Poppy fame, former secretary of the Royal Horticultural Society, wrote me as follows :

" My own view is that the seeds rest in the soil in a state of suspended animation. No active rays can reach them—so they rest. I have experience of two or three cases.

" (1) Having a large bed of seed daffodils, I wanted to eliminate the weeds, as previous experience had told me how extraordinarily difficult it is to weed a bed of seedling bulbs badly infected with grass weeds. So I obtained some soil (heavy loam, almost clay) from the bottom of a 12 ft. deep grave in our churchyard and I broke that up all over the surface of the bed. Result—not one *grass* weed, but hundreds of *gorse* of which there was not a single plant anywhere near.

" (2) A railway cutting was being made through the edge of the chalk down. Three or four years

[1] See Chapter XXI, p. 241.

after noticeable numbers of the Lizard Orchis appeared where the chalky refuse had been piled.

"(3) A neighbour of mine cut down a wood with one wild pear tree in it at least 100 years old. At one corner only of the field then made, there came up thousands upon thousands of common *Papaver somniferum*, and though I inquired in the neighbourhood I could not find anyone, not even the oldest farm hand, who had ever seen the plant before."

I have another letter on the same subject from Mr. Fred F. Chittenden, Director of the R.H.S. Gardens at Wisley, as follows:

"You ask a very difficult question, but many recorded instances in our *Journal* almost compel us to believe that certain seeds are able to survive long burial uninjured. Many alleged instances of this survival can doubtless be explained by assuming rapid infection of newly broken ground by the various means which plants have (or use) of distribution. I do not think, e.g. that we need invoke anything else to explain those millions of scarlet poppies that made the river fields of the Somme such a blaze of glory to the natural eye as they will ever be in our country's eyes, nor to account for the colonies of rose bay willow herb that so quickly populate a clearing in the woods of the Surrey Highlands. I cannot but think suspension of respiratory changes through high concentration of CO_2 may be the cause of preservation, but on that I have a great deal to learn."

The harvesting and sterilising of soil is carried on by florists, and I have seen in the Virginian tobacco fields the soil being burnt in mounds before the seed is sown, in order to protect the minute tobacco seed from growth of weeds. It is an old saying that "earth is the mother of weeds and the foster-mother of flowers."

One of our greatest problems was to fix the slopes from banks and cuttings.

In 1832, many years before I was born, my father, when an assistant engineer to Mr. Robt. Stephenson on the London and Birmingham Railway (now the London, Midland and Scottish Railway), described to me the difficulties encountered in its construction, through the same Lias formation, a few miles to the east of our line. They had no precedent then to tell them what inclination ought to be given to the slopes, which they made 1½ to 1—that is, 1½ ft. horizontal for each one foot rise.

I therefore called on my good old friend the late Mr. Francis Stevenson, then the Company's engineer at Euston, and he gave me some most valuable advice. He said that there was neither a bank nor cutting between Euston and Rugby that had not slipped at some time or other. I told him I intended to make ours 3 to 1 and hoped it would suffice. He said this was right, and added, "Do not make the slopes steeper than this anywhere in the Lias." The results have confirmed this view, and the Great Central Railway is remarkable for the stability of its slopes. Mr. J. T. Middleton, the contractor, knowing only too well the sinister history of the North-Western banks, had devised a most excellent method for carrying out the great cutting at Rugby which contained over 1,250,000 cub. yds. I have dealt more fully with this subject in Chapter X.

On some parts of the line there was a great scarcity of water, and a young lady, the daughter of a local vicar, who was said to be able to "divine" its presence, kindly offered Mr. Middleton to try her powers. She was successful in finding water close to some houses occupied by the workmen, and (what was perhaps more curious) she indicated the presence of water at a point at which a water main existed below the surface of the ground. But her attempt to find water for one of the stations failed, owing perhaps to the fact that water was not present in that area at all.

At Marylebone, for the purpose of the terminus, 1,000 houses had to be demolished. These represented some 5,000 to 6,000 chimneys, with the result that the chimney-sweepers of these houses finding their occupation gone, appealed to the Company, who kindly compensated them. A charwoman, however, who also had lost her clients, without waiting or appealing to the Company or coming to any of us, went and hanged herself: we did not even know of her existence until her death was reported.

The date of the cutting of the first sod was November 13, 1894, and the railway was opened for public traffic March 9, 1899.

CHAPTER V

TUBE RAILWAYS OF LONDON (1893–1907)

It was the late Mr. James H. Greathead who first conceived the idea of deep-level, cast-iron tubes through which trains might run beneath London. He had carefully studied the London geological strata, and had come to the conclusion that in the future the cost of constructing shallow railways such as the Metropolitan and Metropolitan District Railways would be prohibitive, and that his tube railways must be placed at a lower level than the gravel bed, and constructed in the Blue London Clay. The accompanying rough section shows why this is so. If a well or boring be sunk in London in many places it will pass through dry and then wet gravel and sand before it reaches the London Clay.

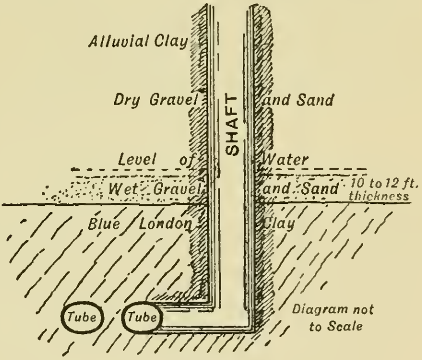


FIG. 2.

Wet foundations for any structure greatly increase the difficulty, danger, and cost of construction. Vertical shafts can indeed be sunk through the water-bearing strata without undue difficulty, but a horizontal tunnel in such a position is very costly to build. These engineering problems were immensely simplified by placing the tube railways deep down in the Blue London Clay, which is drop-dry, and has the consistency and appearance of chocolate. My brother Sir Douglas and I were interested in sinking forty-six lift shafts; all of them had to pass through 10 to 12 ft. of wet gravel and quicksand before reaching the London Clay.

The tunnelling was done with the aid of the Greathead shield. This can be very simply described. Let the reader imagine a table napkin rolled up and put in a napkin ring to keep it in place and form, with the ring pushed to one end of the napkin. The napkin represents the finished tunnel lined with cast-iron plates, and the ring indicates the shield in direct contact with the London Clay. The men work under the protection of the shield, which supports and prevents the superincumbent clay from falling in upon them. As the shield is slowly pushed forward by hydraulic power, additional iron plates can be fixed under cover of the shield.

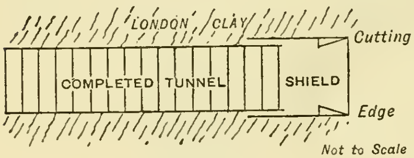


FIG. 3

Amongst the many great advantages gained by the use of the shield, for the most part too technical to be described here, not the least important is speed of advance, not only on the score of economy, but because the swelling of the London Clay, so soon as it is exposed to the air, produces irresistible pressure. It is found that if the working face in such a tunnel is left standing in a vertical position, at the end of twenty-four hours the surface will have bulged about an inch. In fact this clay is, within certain limits, elastic like india-rubber. Hence the more rapidly a tunnel can be driven forward, the less is the subsidence of the surface.

The shield is necessarily rather larger in diameter than the finished tunnel, and as it advances it leaves behind a concentric cavity round the tunnel about 2 or $2\frac{1}{2}$ in. deep. Some means had to be devised for filling up this hollow surrounding the iron plates with Portland cement, otherwise the houses and streets above would have settled down all along the line of railway. The difficulty was solved by the invention of the Greathead grouting machine. A circular hole is provided in each plate through which liquid cement can be forced as the shield advances; the cement solidifies in between the tunnel plates and the clay, and thus not only prevents subsidence, but also protects the tunnel from external corrosion as long as it continues to exist.

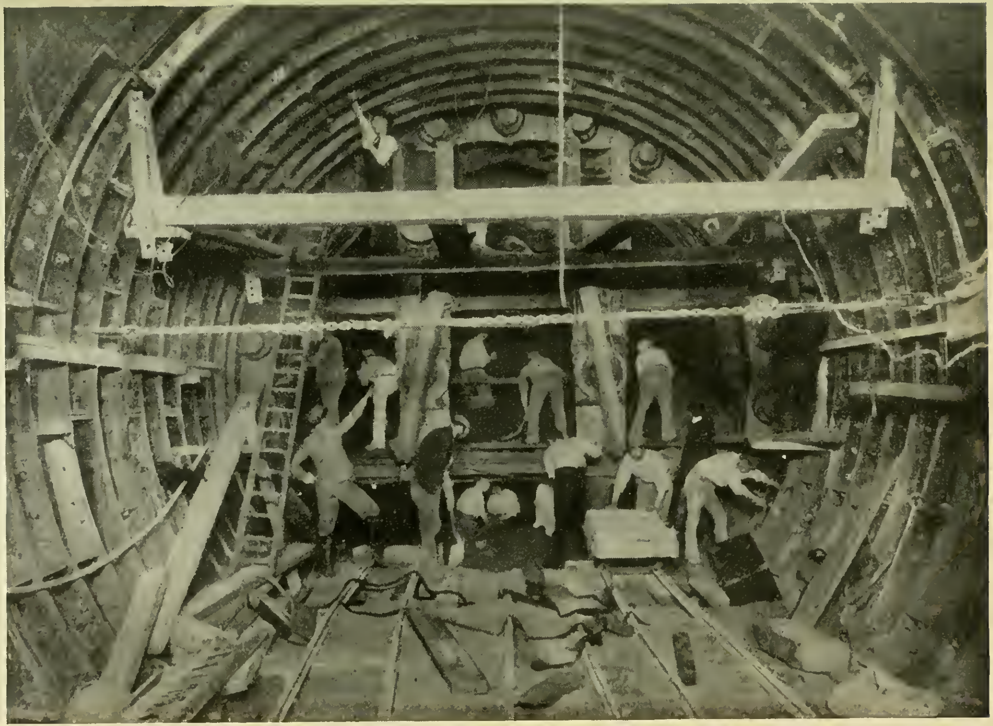
Sir Douglas and I were joint engineers for two of the tube railways, with Mr. Greathead, until the latter's premature death. We used the grouting machine many thousands of times with complete success.

It has also proved of inestimable value in repairing ancient buildings of all kinds; though it was many years before I could induce my architectural friends to realise its great advantage.[1]

[1] Some account of the grouting machine will be found in the chapter on Winchester Cathedral (Chapter XII, p. 129).

The earliest tube was the City and South London Railway (begun in 1886), the internal diameter of which is 10 ft. 6 in. but is now being enlarged. Twelve years later began the building of the Great Northern and City Railway. It differs from all other electrical tubes in that the tunnels were made large enough to accommodate the ordinary rolling stock of the Great Northern Railway. The diameter of the tunnels is 16 ft.; they are, therefore, much more roomy and airy than the other tubes, and are well ventilated. The Great Northern Railway Company gave very strong evidence in favour of the project before the Parliamentary Committee. It was to be, in effect, the City terminus for the suburban trains of the Great Northern. That company undertook to run a minimum number of 50 trains each way per day, and to increase them if desired to 100. Had this been carried out, it would have been a highly prosperous concern. Unfortunately the policy of the Great Northern Company underwent some changes, and the line, although built for their use and convenience, has never had a Great Northern vehicle through it. Now, however (1924), it is again proposed to construct a physical junction with the Great Northern Railway.

The other tube railway for which my brother and I were engineers, in conjunction with the late Mr. W. R. Galbraith, is the Charing Cross, Golders Green, and Highgate, which on the map of London forms approximately the shape of the letter Y; the left hand of this letter going to



GREAT NORTHERN AND CITY TUBE RAILWAY.

Excavating tunnel 30 ft. in diameter. Photographed unexpectedly—all the men at work.

Euston, Hampstead, and Golders Green, the right hand to Kentish Town and Highgate. The railway was opened for traffic on June 22, 1907.

In choosing a site for one of the intermediate stations I, and two other officials, had a rather curious experience. Aided by a large-scale map of that part of London we were trying to find suitable property for the station. A somewhat poor-looking house presented itself, entered by a passage from the street and closed by swing-doors. We walked along the passage, but no one was to be seen. We then entered a kind of hall or large room, the sides and ends of which were wholly of looking-glass, reflecting us in interminable vistas wherever we looked. The door swung to and closed; it also was of looking-glass. There was a handrail fixed round the room, a single strong round bar of brass, 4 ft. from the floor and 4 in. from the glass. We were unable even to guess the purpose of such a hall. But our perplexity was of short duration, for another small door in the looking-glass suddenly opened, and although it was about 12 noon, and broad daylight from the skylight above, there entered a young woman clad in nothing but silk tights! She paid no attention to us, nor seemed in any way disconcerted on finding three men in the room, but, rushing to the side of the hall and seizing the brass rail, began her antics and contortions—the chief aim evidently being to ascertain to what extreme height she could kick! We had fallen, unawares, on a training school for ballet girls. The incident made a very disagreeable impression on my mind, and I was glad when this particular house was demolished.

When the necessary Bill for constructing the railway came before Parliament, the Company were opposed by a local committee formed in Hampstead under a chairman who has recently died, for whom I had much respect. They held the opinion that the tunnel passing under Hampstead Heath would drain away all the water, and even all the moisture, in the ground, would dry up the ponds, and consequently that all the trees, the gorse, and even the grass would be killed, and the famous "Heath turned into a Sahara." It was also pointed out that the tube might possibly collapse and let down the surface of the Heath, and that, in short, the days of the latter were numbered. These predictions were so far from being fulfilled that the whole of the tunnel was perfectly dry, and water had to be laid on from the Water Company's main to enable workmen to carry on the construction.

The tunnel was, for nearly its whole length, in London Clay and therefore dry, but between Tottenham Court Road and Euston it ran out of the clay and entered the Woolwich and Reading beds. At this point alone water was met with, and compressed air had to be used. The pressure of the air was raised and air-locks became necessary. Work in such "air-locks" is, it can be imagined, not very pleasant. The principle is that of the "diving-bell."

The accuracy with which the work was executed by the engineers and contractors was remarkable.

For instance a shield was started at the Hampstead Heath station, and travelled south under Haverstock Hill Road; another was driven from Belsize Park station, and went north. These shafts, 1,300 to 1,400 yards apart, were off the centre line and Haverstock Hill Road itself has sinuosities, but when the shields met they were edge to edge, and were left in to form a portion of the iron lining of the tunnel. The actual variation from absolute accuracy was as follows:

Error in direction	One-quarter of an inch.
Error in level	One-eighth of an inch.
Error in length (4,000 ft.) . .	Seven-eighths of an inch.

The station at Hampstead Heath is 291 ft. below the surface and is the deepest in the world. Under the heading "C3 Nation's Climb" *The Times* of March 29, 1921, published the following from its Medical Correspondent:

"To a medical man one of the most thrilling sights which Easter Monday afforded, was the pilgrimage of this C3 nation up the steps of the Hampstead Tube Station. It was really an astonishing spectacle, and, having found it, one stayed to investigate. For this is the deepest tube station in London, perhaps in the world, and the spiral stairway has over 300 steps.

"And yet a large number of people preferred the stairway to the lift—and came up smiling. They were of all ages—middle-aged, and even-more-than-middle-aged men, middle-aged women, boys and girls, children. One might have expected to see some of them at least in states of severe exhaustion. Not a bit of it: they reached the top, the great majority of them, sound in wind as in limb, and merry as the holiday makers in the roadway outside.

"And they came up quickly too, a few of them two steps at a time, for part of the way at least. The curiosity which made the observer descend was rewarded by the discovery of very few pauses, not three on the whole stairway, on which there must at that moment have been 100 people." [1]

The passenger lifts at the stations are all tested by the Board of Trade. One or two of them are loaded with a weight of pig-iron greater than the weight of a packed load of passengers. The lifts are then allowed to fall, with the objects of ascertaining, not only that the ropes are fully capable of bearing the strain, but also that the automatic safety catches will come into operation in case of need. In all the tests this fall has never exceeded a few inches: and as the ropes are made to carry a weight twenty times their maximum load, no anxiety need be felt. The other lifts are tested with a living load of eighty persons, including workmen, the Government Inspector, and the engineers and contractors, who show in this way their confidence in the safety of the apparatus. Seventy-eight lifts have been thus examined in one day. The mere walking in and out and ascending and descending for several hours was in itself tiring. Moreover, as none of these lifts had previously been tested, the strain upon the nervous system was considerable. By the end of the day we were all fairly well "played out."

[1] *The Times*, March 29, 1921.

The introduction of the escalator, or travelling staircase, has now done away with the necessity for lifts in many places.

When the tube railways were proposed, an effort was made to obtain the consent of the London County Council, Borough Councils, and other authorities to a scheme which would have much simplified the stations and passages. Under this proposal each station would have been placed directly beneath the street, with steps leading up to the pavement. The lifts would have delivered passengers straightway on to an "island" platform, on a level with the floors of the trains. Such a station exists at the Bank terminus of the Waterloo and City Railway, and the interference on the footway is reduced to a minimum. Had it been necessary, however, to purchase a block of property in order to effect this arrangement, the cost would have been prohibitory.

If this system had been allowed on other stations throughout London, the saving both in convenience and in capital cost would have been very great. Co-operation between the various Companies, and also between them and the public authorities, would have rendered unnecessary many of the long cross passages, which are such a vexation to the Underground traveller to-day. The reason for the existence of these passages is, to a large extent, the high value of property with frontage on to a main street. By going a little way up a side street, suitable sites for stations could be purchased at comparatively low cost.

CHAPTER VI

OVERHEAD, RACK, AND ROPE RAILWAYS

(1) The Liverpool Overhead Railway (1887-93)

The great need of some kind of rapid transit along the entire length of the great Liverpool Docks had long been felt, when the proposal for an elevated or overhead railway was urged by Sir William Forwood and other leading men of Liverpool.

An Act of Parliament passed in 1887 provided for a line connecting the most northerly dock, the Alexandra, with Herculaneum at the extreme south, a distance of 6⅓ miles.

A short extension at the northern end to Seaforth Sands on the Lancashire and Yorkshire Railway, and an extension through a tunnel at the southern end to Dingle, were added later.

The trains, electrically driven, run at intervals of 5 minutes in each direction. There are sixteen stations in all and the time occupied in the complete journey is 28 minutes.

In 1919 the number of passengers carried was 22,440,000 and in 1920, 21,020,000.

The engineers were Sir Douglas Fox and Mr. J. H. Greathead; Mr. S. B. Cottrell and myself were in charge of the works.

The problem of applying electrical power to the haulage of traffic was solved by the late Mr.

Thomas Parker, one of the most capable and far-seeing electrical engineers of the time. The signals are set by the trains themselves.

The railway was built on steel columns or stanchions with girders of greatly varying size and span, which had to be placed so as not to interfere with the Mersey Docks and Harbour Board. The dock lines were on the street level, and the new railway had to be carried above them.

The many different types of steel girder bridges required, presented a series of troublesome problems to our partner Mr. G. A. Hobson (who patented the arch flooring now so generally adopted throughout the world), and to Mr. J. W. Willans, who had won the contract in competition with others ; and the successful execution of this difficult and important work was very largely due to his untiring energy and skill.

The preliminary operations took a great deal of time.

Much delay was caused by the necessary alterations to the dock lines, and the removal of several police stations, customs depots, and other buildings. Mr. Willans designed a steel erector which enabled each complete span of 50 ft., and its flooring, to be transported over the completed portion of the railway and lowered into place intact. The design and testing of this erector meant a long business. One of Mr. Willans's partners facetiously estimated that, at the speed attained in the first few months, it would require 100 years to complete the railway ; but if the Company would dismiss Mr. Willans, and place the contract in his (the partner's) hands, he would undertake to do it in half the time.

However, when the Erector was completed and in working order, as many as twelve spans of 50 to 70 ft. each were often fixed in their permanent positions in five and a half working days. This would represent about 650 ft. of finished viaduct. From first to last this was effected without a single mishap. The total number of spans is nearly six hundred.

(2) The Snowdon Rack Railway (1894–1896)

In the year 1894 a proposal was made for the construction of a rack railway from Llanberis to the summit of Snowdon, to which my brother and I gave our most careful thought.

There are several kinds of rack. There is the *Riggenbach*, or ladder rack, in which steel girders constitute the sides of the ladder, with cross pieces representing the rungs. Another is the *Abt*, consisting of one, two, or three flat bars bolted together, in which deep notches are cut at regular intervals, and into which the pinions on the locomotive are geared. Another kind is that which was designed for Mont Pilatus by that brilliant Swiss engineer the late Colonel Locher, of Zurich, in which the gradient is no less than 1 in 2, some of the wheels being placed horizontally so as to grip a central rail.

We had been strongly advised to adopt one of these three methods; and as I was in Switzerland at that time I asked Colonel Frei, President of the Swiss Confederation, if he could furnish me with particulars of some of the rack and rope railways existing there. He not only presented me with the drawings and particulars of every such railway in Switzerland, but invited me with my two colleagues, who were in Berne, reporting on the Simplon Tunnel, Signor Colombo of Rome, member of the Roman Senate, and Herr Wagner of Vienna, Inspector of Government Railways, and engineer of the great Arlberg Tunnel, to accompany him and the ministers of his Government for a two or three days' excursion into the Bernese Oberland to see some of the rack railways in operation.

The President took us to the Kleine Scheideck, where a banquet, at which he presided, was given in our honour. The next morning we started on our descending journey, in a spacious compartment together with the President, the Ministers for War, Education, and Finance, Colonel Locher, Dr. Edouard Sulzer, of Winterthur, and some other engineers. One of the latter sat opposite to me near the door and explained how absolutely safe the system was. On each carriage there were two powerful hand brakes and on the engine no fewer than five. These were the automatic speed brake, which immediately stopped the train if the speed exceeded 5 miles per hour; the steam brake; the compressed air brake, and two hand brakes.

"You see," he explained, "that if one brake failed, there are still four left, and if by combination of ill luck *two* failed, there would still be three available, so that the train is really the safest place in the world. Nothing could possibly happen."

Just at that moment there was a great jolt, and a crash, and we began to travel rapidly down the 1 in 5 gradient. My friend attempted to jump out of the window, but I hung on to his coat tails and held him.

But the brakes did act, and the train came to a stop, and he and nearly all the others alighted more or less precipitately from the carriage. I was left in my seat, and Colonel Frei kept his in the opposite corner of the carriage. "Well, Colonel," I remarked, "you take this incident very coolly." "You see," he replied, "I am an artillery officer, and have learnt by experience that on such occasions it is always best to sit still."

However, we all had to leave the train. The driving cog wheel on the engine had mounted the rack, had smashed the rack itself, and had bent the driving-axle of the locomotive so that it was unsafe to use it. The whole party, including two ladies of seventy years of age, had to walk down to Grindelwald from an altitude of some 5,000 ft.

I thereupon reported to London that this description of rack had had an accident, and that we were advised by the Swiss to adopt another of the three designs. This we did, taking care to adhere strictly to the Swiss design except that where they used cast iron we went one better and used steel. We also adopted Winterthur locomotives, and decided to employ experienced

Swiss drivers. These locomotives were employed in the construction of the railway, running over unpacked sleepers and irregular permanent rails. Mr. Frank Oswell was our Resident Engineer and Messrs. Holme & King the Contractors. The work was completed without hitch of any kind.

Before the line was opened to the public, we invited the leading officials of the chief English railways to inspect this mountain railway, which to most of them was a novelty. Some forty or fifty of the leading men experienced in railway construction accepted our invitation. We asked them to examine the line critically and took them up at noon to see the mountain under varying conditions of sunshine and fog, and at the summit in snow. At 11 p.m. they again ascended the mountain to see the railway by moonlight and also in fog and snow. They were all delighted and described it as "a first-class bit of work."

The railway had been examined and severely tested by the railway inspectors of the Board of Trade. On the following Whit-Monday the first passenger train carrying 72 passengers went up at 7.30 a.m. Every seat was filled. They found the summit in deep snow and were all delighted with their experience.

(3) The Dorada Rope Railway

Some account of a remarkable "rope railway" engineered by my late firm in South America may be of interest, at this point, to my readers. Communication was greatly needed for goods traffic between the Dorada Railway in the valley of the Magdalena River in the Republic of Colombia, and the Esperanza Valley, in which the important city of Manizales stands isolated by the Cordillera of the Andes. Access by rail is impossible at anything approaching a reasonable cost, and therefore recourse has been had to an overhead ropeway. But even this presented considerable difficulties, for the distance is $45\frac{3}{4}$ miles, and the altitude of the Andes over which it passes is 12,000 ft.

Till quite recently the transport of goods, up to 6,000 ft., was effected by bullocks, as they can best resist the heat ; for the remaining 6,000 ft. mules were employed, as they are better able to stand the cold and the snow. The same method was used for the descent on the other side.

The rope line is divided into 15 sections, some of which are as much as four miles in length. Each section has an endless rope passing over sheaves on suitable steel trestles, which have to be high enough to prevent the carriers and loads from touching the ground. Some of these trestles are 216 ft. in height, and the greatest stretch of rope between trestles is 2,916 ft., or considerably more than half a mile. The weight in each carrier is 462 lb., or one-fifth of a ton.

Several pianos and other heavy articles have been successfully carried over at this great altitude, but the chief traffic consists of coffee, none of which reaches England, but is consumed in New York. I was showing some friends the photographs, when a young lady asked me what was the object of the line. I replied that it was to deliver coffee. Said she, quite innocently, "It must be very cold before it reaches its destination!"

The line is now complete. It is intended eventually to utilise the water-power of the mountains to drive all the machinery and to conduct the traffic.

The rope line was constructed with much skill and success by Mr. Lindsey, the General Manager of the line—and formerly the manager for the Contractors, Ropeways Limited—under the advice of my former partner Mr. Ralph Freeman.

CHAPTER VII

THE SIMPLON TUNNEL (1894–1905)

THE route over the Alps, by way of the Simplon Pass, has existed in one form or other since time immemorial; and although originally it was but a footpath, yet there are remains of Roman culverts and bridges. In March 1801, soon after the battle of Marengo, the present roadway was begun by order of Napoleon, and it was finished in September 1805. The length of the highway is 37½ miles; 611 bridges and culverts had to be built, and seven galleries driven for protection from avalanches, or through rock.

Between the years 1852 and 1893 no fewer than thirty different proposals for traversing the Simplon by railway were put forward. Of these, two were for scaling the mountains without subterranean work: the remaining twenty-eight were for tunnels of various altitudes and lengths. In 1891 the Jura-Simplon Railway Company brought forward their first project, and subsequently, in 1893, the one actually adopted—namely, a low-level tunnel with easy gradients. This was indeed the only rational method; in no other way could the Company hope to compete with other Alpine railways, and secure a return upon the heavy capital outlay.

By adopting the existing level of the railway at Brigue, all expense of heavy approach lines and helical tunnels on the Swiss side was avoided. The railway enters the mountain a few feet above the level of the Rhone. The greatest depth reached below the surface is 7,005 ft., beneath the slopes and crags of Monte Leone, the highest mountain of the Simplon range (11,684 ft. above sea level). This is by far the greatest depth to which man has ever been below the surface of the earth. After passing under the Lake d'Avino, the tunnel proceeds to its southern portal at Iselle. The total distance is 12 miles 537 yards. This length includes two short curves, one at each end; but the "gallery of direction," which for triangulation purposes is driven in a straight line from end to end, is 21,576 yards long.

The following Table gives the comparative lengths and altitudes of the Alpine tunnels:

	Mont Cenis.	St. Gothard.	Arlberg.	Simplon.
Length of tunnel	14,052 yds.	16,387 yds.	11,199 yds.	21,657 yds.
Altitude of the highest point above the sea	4,245 ft.	3,786 ft.	4,299 ft.	2,313 ft.
Maximum gradient in the tunnel	1 in 45	1 in 172	1 in 66	1 in 143

Not only is the Simplon the longest tunnel in the world, but it is also the lowest in altitude of these four.

The position of the entrance on the south side was determined by two factors—namely, the climate, and the extreme narrowness of the Diveria valley. It was well known that sleighs could reach Iselle every winter, since the depth of snow up to that point was never formidable, and that a short distance higher up the valley becomes impassable in winter, but it was possible to arrange there the various buildings and installations necessary at the end of the tunnel.

The position of the portals having been thus fixed, the gradients also were practically settled. It was obvious, from the experience of engineers in previous tunnels, that the gallery must be

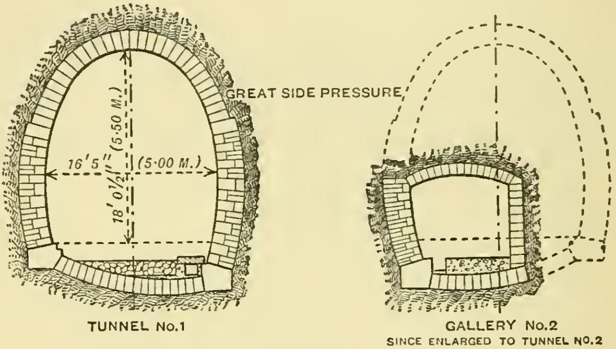


FIG. 4.—SECTIONS OF TUNNEL No. 1 AND GALLERY No. 2.

driven on an ascending incline from both ends, so that the water might flow away by gravitation. In the Mersey tunnel a minimum gradient of 1 in 500 was found to give the water a sufficient flow. In 1893 the same gradient of 1 in 500 was adopted for the northern half of the Simplon tunnel; a gradient of 1 in 143 for the southern half of necessity followed.

Instead of one tunnel for a double line of way, as in the St. Gotthard and Mont Cenis, provision was made for two single-line tunnels (Figs. 4 and 5)

55·8 ft. apart (between centre lines), connected by oblique cross passages at every 218·7 yards. It was arranged that one tunnel only should be built at first, with a parallel gallery; this gallery has since been enlarged into the second tunnel.

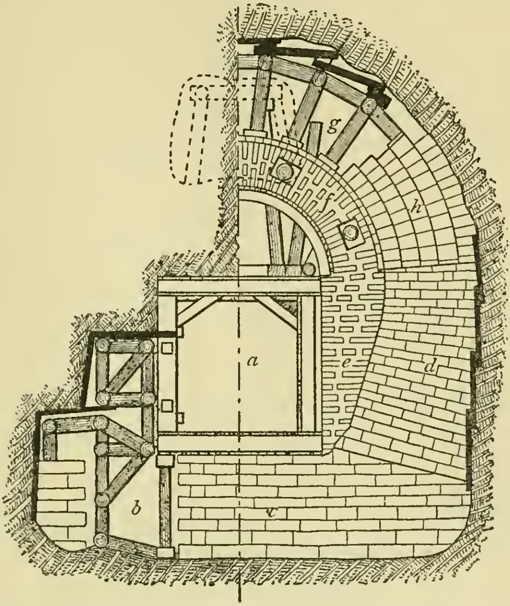


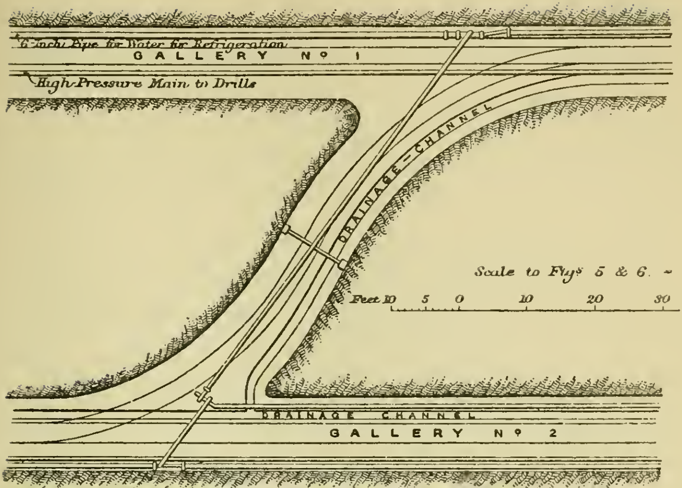
FIG. 5.—CROSS SECTION SHOWING STAGES IN CONSTRUCTION OF TUNNEL AT 4,400 KM., OR 2 MILES 1,292 YARDS.

a. Advance gallery with Steel Beams and concrete.
b. Timbering for excavation for Invert.
c. Permanent Invert.
d. Permanent Side Wall.
e. Temporary Wall for supporting Temporary Arch.
f. Temporary Arch.
g. Timbering for permanent Arch.
h. Permanent Granite Arch 5 ft. 6 in. in thickness.

The importance of providing two single-line tunnels cannot be over-estimated. Thus whenever repairs have to be executed in the arching of the work without stopping the traffic, they can be far more easily effected if there are two, than in one tunnel carrying the two lines. Trains can be diverted for the time being, and the timbering for the repairs does not have to be so arranged as to allow traffic to pass. Again, if a train is derailed, passing vehicles are not exposed to the danger of collision. Or again, if the lining of the tunnel is subjected to great pressure, this is far less in a single-line than in a double-line tunnel. How important a consideration this is, has been proved by actual and very anxious experience. Ventilation is moreover greatly simplified by the existence of two tunnels.

And these are also lined throughout with masonry, to avoid the risk of a fall of rock on to the line during traffic. Great thicknesses of lining were found to be necessary in places. At 2 miles 1,292 yards from Iselle the granite blocks, of which the lining consists, are as much as four and a half feet thick.

Doubts having been cast by certain engineers upon the possibility of constructing the tunnel, the Swiss Confederation requested the Governments of Italy, Austria, and England each to nominate an engineer having experience of tunnelling, to form a "commission of experts" to examine the programme and proposals, and the plans and estimates, and to report to the President of the Swiss Confederation. The Government of Italy nominated the Hon. Giuseppe Colombo, Member of the Senate, and afterwards Minister of the Treasury; Austria appointed Herr C. J. Wagner, Chief Government Inspector of Railways in Vienna, and the celebrated engineer of the



ADVANCED GALLERIES Nºs 1 & 2, WITH TRANSVERSE GALLERY

Fig: 6.

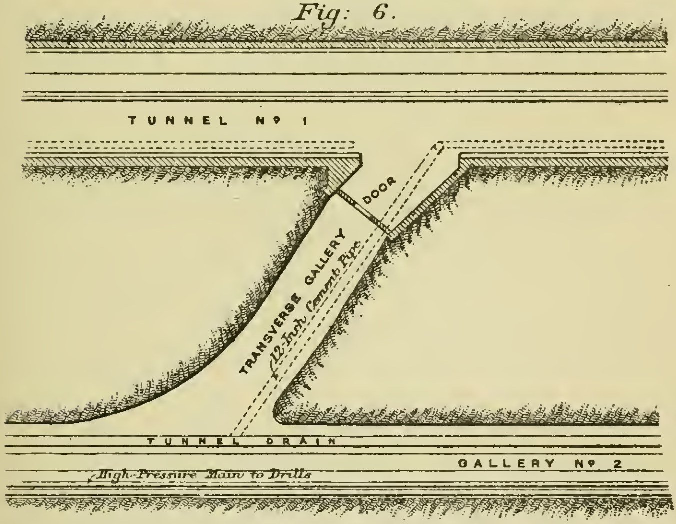


FIG. 6.—COMPLETED TUNNEL No. 1 WITH PARALLEL GALLERY No. 2 AND TRANSVERSE GALLERY.

Arlberg tunnel ; the British representation was myself. The commission sat at Berne for some time considering the plans and estimates, examining the proposed systems of drilling and ventilation, and generally going into every detail; after visiting the site of the tunnel and the proposed entrances, we presented our report to the President and the Swiss Federal Council in July 1894.

Herr Brandt, who unhappily died soon after the works had been begun, had had a wide experience on the St. Gotthard tunnel, which enabled him to devise and introduce many improvements in the machinery and installations. His place was taken by Colonel Locher, of Zurich, the celebrated engineer who constructed the Pilatus railway, the most daring piece of work of its day. Colonel Locher planned and constructed all the installations at Brigue and Iselle. This was a work of great importance and magnitude, and was carried out with a rapidity which has never been equalled. Indeed the financial and mechanical skill possessed by that remarkable combination of men—K. Brandau, Edouard Sulzer, and Col. Locher—was only equalled by their dogged determination, which absolutely refused to admit defeat where so many pronounced the difficulties insuperable. Dr. Sulzer-Zeigler stated in public that, had the geologists been quite accurate in their preliminary investigations and reports, and had they correctly anticipated the dangers and obstacles which were eventually met with in soft rock, the "Great Spring," or river of cold water, the high temperatures and hot springs, and the "creep" or lifting of the floor, no one would have dared to undertake the contract, and the tunnel would never have been constructed. Switzerland is rightly proud of the men who overcame such difficulties as these.[1]

The specification stipulated for excellent ventilation in all working places in the tunnel. A temperature not exceeding 25° C. (77° F.) was to be maintained by means of jets of sprayed water. Further, a good supply of drinking water was to be available in all working places; free baths were to be provided for the workmen; healthy lodgings and good food at low prices were to be placed within their reach. This specification was in large measure drawn up by the contractors. Is it an exaggeration to say that the solicitude and care which they showed for their workmen have been an object-lesson to the world?

The rock consists chiefly of gneiss, mica-schist, and (on the Italian side) antigorio gneiss; but in some places, particularly at a point about 2·73 miles from Iselle, limestone was encountered. This rock, commonly known as "sugar marble," is lustrous in appearance, and highly charged with springs of cold water, at a temperature of 52° to 62·6° F. So long as the Brandt perforators had good hard rock in front of them, they made splendid progress; but when the soft rock was reached, and timbering had to be used, the rate

[1] I should wish my readers to associate with the other names mentioned in this chapter those of Dr. Pressel, Dr. von Kager, Dr. Hæussler, Herr Beissner, Herr Colomb, director of the Federal Railways, and Herr Zollinger, chief engineer of the Company. It is sad to think that nearly all the leading men concerned in the tunnel have passed away.

of advance naturally fell off, and in some places excavation by hand had to be adopted. Where the geological beds were horizontal, great pressure was encountered and much heavy timbering was required.

The triangulation was entrusted to Herr Max Rosenmund, Engineer of the Federal Topographical Department, and subsequently Professor of Geodesy at the Federal Polytechnic School of Zurich. His calculations proved extraordinarily accurate. The actual difference in the direction of the tunnels at their meeting was $4\frac{1}{3}$ in. The total length was found to be 31 in. less than Rosenmund calculated—almost precisely the expected error.

Full particulars of the water-supply and channels, as also of the Brandt drill and method of working, have been given in a paper published by the Institution of Civil Engineers by my son, the late Mr. Charles Beresford Fox, Assoc.M.Inst.C.E. I shall only describe these very briefly.

The Brandt drill consists of a stretcher-bar (itself an hydraulic ram) mounted on a portable carriage, and provided with three hydraulic engines each actuating a drill. This is $2\frac{3}{4}$ in. in diameter, and can be worked in any direction: it can be advanced or withdrawn at any desired speed, and the changing of the tool can be effected in 10 seconds. The drill is rotatory in its action and non-percussive, being kept up to its work with a pressure of 10 tons; and as the discharge-water is delivered through the centre of the tool to the cutting edges, the dust produced is at once turned into mud, and at the same time the steel is kept cool.

The sad experience of the St. Gotthard tunnel emphasised the great necessity for ameliorating the conditions of work. In building the St. Gotthard tunnel, between 1872 and 1880, no fewer than 800 of the workmen died, including both the contractor and the engineer. This enormous death-roll was essentially due to defective hygienic conditions, to the high temperature and small supply of air in the interior of the galleries, to the severity of the climate, and to the sudden transitions from heat to cold. Other contributory causes were the want of proper provision for changing the men's wet clothes, and the dust produced by the drilling machines. A special disease called miner's anæmia, now better known as "anchylostomiasis," due to the presence of a small worm, *Dochmius duodenalis*, in the intestines, was terribly active in the St. Gothard tunnel works.

In the Simplon tunnel, where the conditions were naturally favourable to the disease, it was absolutely unknown. Excellent arrangements were made for the complete ventilation of the innermost workings and the most advanced galleries; for every cubic foot of air which was blown into the St. Gotthard tunnel, twenty-five were supplied to the workmen in the Simplon. Not only did the ventilating fans keep up a steady current of air along one gallery and back by the other, but, by an ingenious system of aspirators, a large volume of fresh air was blown into the dead ends of the galleries, which were thus kept perfectly fresh. The current was strong enough to blow a man's hat off. In fact, such a thing as vitiated air was unknown throughout the works, and would have been regarded as a slur on the management.

I take this opportunity of urging very strongly the immense importance, from every point of view, of supplying every working place in a tunnel with an ample volume of fresh air. Much more work is done, the health of all is preserved, and the many indirect economies result in reduced cost. Notwithstanding all my efforts, I have never known the working face of a tube railway, and very seldom that of an ordinary tunnel, to be properly ventilated. I must, however, put on record the excellent ventilation provided in the Greenwich Footway tunnel and the Blackwall, Rotherhithe, and other tunnels driven under compressed air, in which a very large volume was forced in between the air-locks and the working face.

Next in importance to good ventilation were the excellent arrangements for enabling men to change their clothing. At each end of the tunnel, and connected with it by a covered line of railway, was a large building fitted with dressing-rooms and hot and cold douche baths. From the roof of the building, which was heated by steam pipes, hung 1,500 ropes passing over pulleys, each with its padlock. On the other end of each rope was a hook upon which the owner could hang all his things, and then, hauling them up to the roof, he left them there during his absence in the galleries.

On his return from work, wet through and fatigued, a man was not allowed to go direct from the warm tunnel into the cold Alpine air outside, but he entered a cubicle where he had his bath, and, having lowered his day clothes, he attached his wet mining garments to the hook and hoisted them to the roof adjacent to the hot pipes, to find them dry and warm on his return to work next day. If his clothes were torn or soiled, they were sent to the laundry on the premises. After changing from his mining into his day clothes, he passed into a restaurant, where he could obtain a substantial hot meal for 4*d.* and, if he so desired, board and lodging for 1*s.* 2*d.* per day. Excellent hospitals were provided at each end of the tunnel, but these establishments were generally empty. Good arrangements for "first aid" were also organised.

In the length of the tunnel, four large rooms were built for the use of the workmen and their tools, trollies, etc. These rooms are 13 ft. wide, 10 ft. high, and 20 ft. long. I am strongly of opinion that every tunnel exceeding a quarter of a mile in length ought to be constructed with a room for the men, furnished with a cooking stove and seats, to enable them to cook their food and have their meals, protected from the draught and smoke of the tunnel.

The Italian miner, even when called upon to work under less favourable conditions than prevailed in the Simplon tunnel, is extraordinarily resistant to disease owing to his sobriety, his simple life, and, above all, the good qualities of his race. The doctors reported how these men recovered with exceptional rapidity from injuries and wounds. Moreover every man was medically examined as to his fitness for the special conditions of his work. The result of this and the other precautions taken was very satisfactory. The total number of lives lost in the Simplon tunnel from all causes was 60. A monument was erected to the memory of these men in May 1905 at Iselle.

The discipline among the workmen was of the highest order. Nearly all of them were Italians, who had done their military training; and so long as they were not interfered with by paid agitators, there were no strikes, and no malingering nor shirking. There was, indeed, one strike. When the men were asked what they were striking for they said they did not know, and went back to their work. They worked in three shifts of eight hours each, and as no man ceased his labour until his successor actually stepped into his place, the boring-machines never ceased operations.

Excellent order and neatness characterised the whole undertaking. Within the boundaries of the installations at both ends of the tunnel no rubbish of any sort was allowed to accumulate. Everything was in its place, and men were constantly employed in sweeping the ground and keeping it clean and tidy. In this respect the undertaking compares favourably with many engineering works elsewhere; and, indeed, it constitutes, from every point of view, a fine illustration of an engineering project efficiently carried out.

Judging from the experience of former Alpine tunnels, the engineers expected to encounter considerable heat. In the St. Gotthard, the maximum temperature of the rock was 87° F.; the temperature of the air varied between 91° to 94° F. and, owing to the stagnation of the air, was insupportable. In the Simplon, although the temperature of the rock was 129° to 133° F. that of the air did not exceed 89° F. This was in no way unbearable, owing to the large volume of fresh air travelling along the galleries, and the use of the spraying devices already mentioned.

In order to obtain the best results in refrigeration, it was necessary that the water should be as cold as possible, and consequently the pipes had to be lagged, or covered in, to exclude the heat of the gallery. The insulation of 10-in. pipes for a distance of 5 to 6 miles was a difficult problem. The husk of rice was for a time used as a non-conducting material, but, owing to stray grains of rice germinating, it had to be roasted. Then the customs authorities, finding this worthless material was being used, charged a high rate upon it coming from Italy, and it had to be abandoned. Finally, charcoal was employed with such excellent results, that the pipes delivered the water to its destination with a rise in temperature of only 7·2° F.

At the southern or Iselle end, the temperature of the rock followed approximately the section of the mountains until a distance of about 2,406 yards was reached. Then, as the tunnel advanced (Fig. 7), the rock-temperature began to diminish.

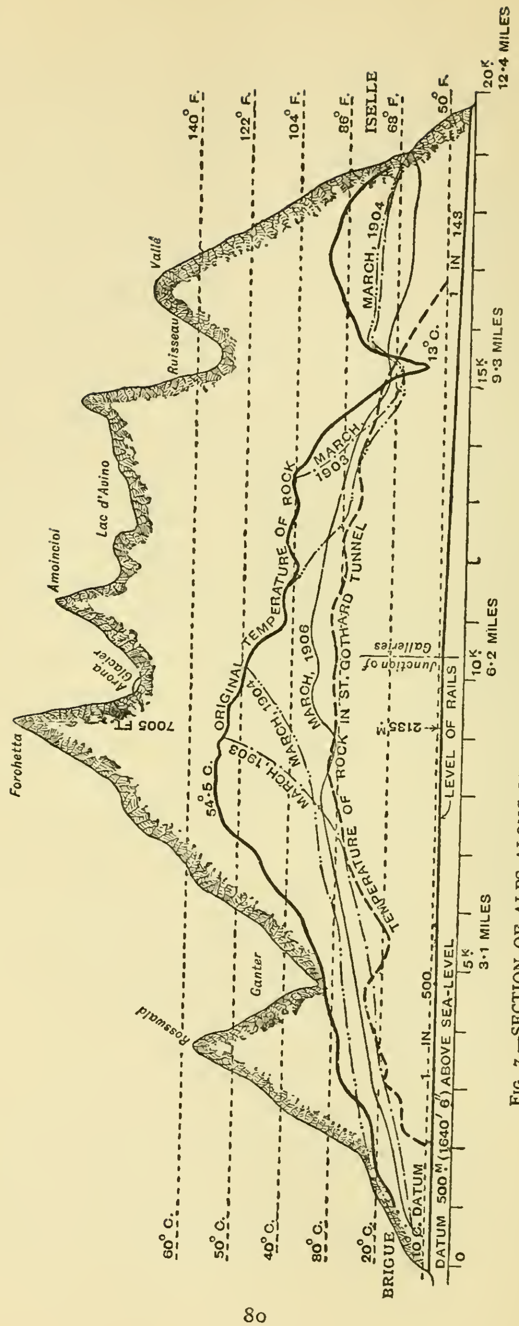


FIG. 7.—SECTION OF ALPS ALONG LINE OF TUNNEL AND CURVES OF TEMPERATURE OF ROCK.

At 4,374 yards it began to fall rapidly. At 4,812 yards it attained the lowest reading recorded. At this point the "Great Spring" was struck, with a flow of 10,564 gallons per minute; the fall of temperature was evidently due to this volume of

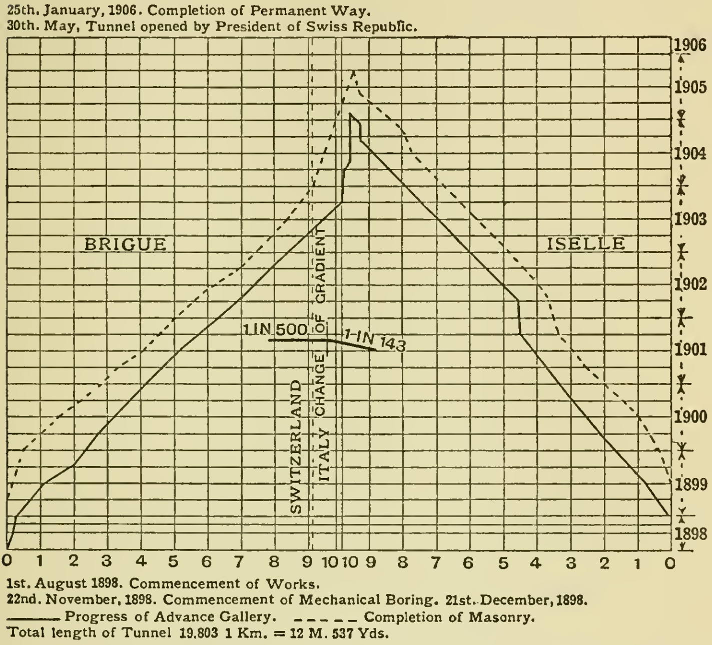


FIG. 8.—DIAGRAM SHOWING PROGRESS OF ADVANCE GALLERY AND COMPLETION OF MASONRY FOR TUNNEL No. 1.

By kind permission from the Proceedings of the Institution of Civil Engineers.

cold water. The first outburst of water was at a very high pressure, estimated at 600 lb. per square inch. Now, however, it issues at atmospheric pressure, and has a temperature of about 64° F.

What relation exists between temperature and depth? Is there indeed any constant relation?

Obviously, in any attempt to plot the depth-temperature curve of the earth's surface, the rapid fall 4,374 yards from the Italian entrance must be eliminated, on account of the exceptional agencies at work. Whatever deductions we draw are influenced by many other disturbing factors, such as the inclination of the strata, and the nature of the rock. Let us assume, however, that at a depth of 33 ft. below the snow-clad summits of the high Alps a uniform temperature of 32° F. may be expected throughout the year ; then, in a total depth of 7,005 ft., we may calculate a temperature-gradient of 1° F. for each 71·5 ft. Probably the observations between 8 kilometres and 13 kilometres furnish the most trustworthy average ; and this selection gives a relation between depth and temperature of 67·5 ft. per degree Fahrenheit.

Fig. 8 shows the rate of progress, both in driving the galleries and in completing the masonry. It was anticipated that this latter would be approximately one kilometre in rear of the advanced headings, and that the piercing of the Alps would be accomplished about November 1903. Actually it did not take place till February 24, 1905. It was hoped that the arching would be finished about March 1904 ; the actual date was September 1905. The diagram shows that excellent progress was made in the gallery on the Brigue side, and that the middle of the tunnel was reached nearly six months ahead of the programme ; but from that point onwards, difficulties and delays occurred, chiefly due to hot springs, and to the downward direction of the drive.

On the Iselle side, work progressed well until a point 2·734 miles from the mouth of the tunnel was reached. At that spot suddenly, and without warning, the "Great Spring" was encountered. This stopped the advance for about six months,

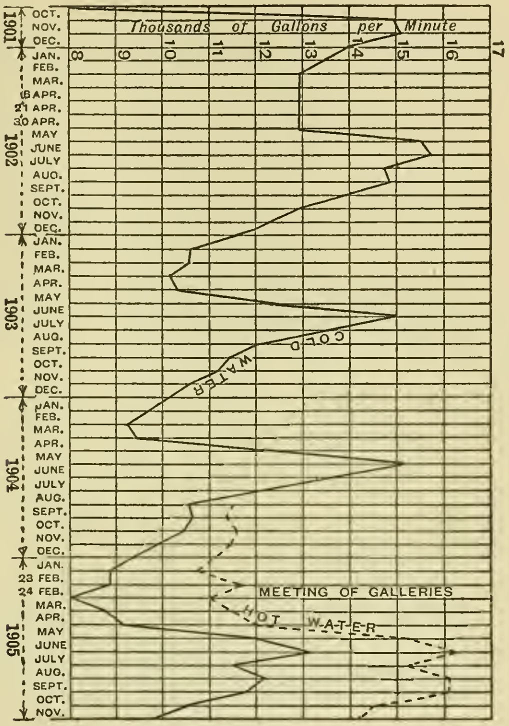


FIG. 9.—DISCHARGE OF HOT AND COLD SPRINGS.
By kind permission from the Proceedings of the Institution of Civil Engineers.

up to September 1901, by which date the soft rock had been traversed, and hard granite again reached. After this good progress was made until September 1904, when hot springs were encountered at a point 5·659 miles from the entrance, with a temperature of 113·7° F. In order to reduce the heat, a pumping installation was established in the tunnel at 2·734 miles ; and pipes were laid along the gallery, by which cold water was forced up the gradient for a distance of four miles to the hot region. Jets of cold water were then thrown into the fissures from which hot water was escaping, and the temperature was thus lowered to the point that the miners were able to stand.

Fig. 9 shows by a full line the flow of cold springs into the workings from September 1901 to December 1905, and, by a dotted line, the inflow of hot springs. The maximum discharge of cold water was 17,081 gallons per minute, and the maximum discharge of hot water 4,330 gallons per minute. The maximum flows of cold water occur at the times of melting of the Alpine snows. The volume of 15,158 gallons per minute in November 1901, was doubtless due to the first tapping of the underground reservoirs.

Another difficulty was the rising of the floor which occurred in several places, even in solid rock, showing the tremendous pressures at work. It became necessary to construct masonry inverts for a very considerable distance, which caused much delay.

The time occupied in the construction of the tunnel was 2,392 days. Without allowance for Sundays, saints' days, and holidays, nor for those occasions on which work was suspended for verification of the axis, or by accidents or strikes, the average daily advance at each face was 13·69 ft., including several months of hard drilling.

If we allow only for the actual days on which the boring machines worked, the progress was 17·45 ft. per day at each face, a result never attained on any other tunnelling work in the world.

In consequence of the delay caused by the difficulties described above, the Swiss headings had reached their culminating point, 5 miles 1,670 yards from the northern end of the tunnel, before the Italian headings were ready to meet them. This point had always been intended to be the

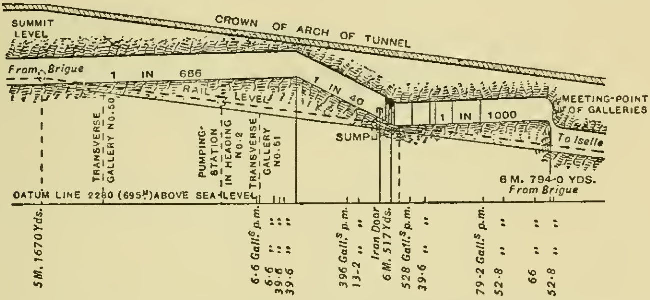


FIG. 10.—CHANGES OF GRADIENT ADOPTED IN DRIVING HEADING FROM BRIGUE BEYOND SUMMIT-LEVEL.

extreme boundary of the workings from that side. In order, however, to save time, it was decided to drive forward as far as possible on a slightly rising gradient, until the top of the future tunnel was reached. This was an advance of 445 yards, to a point 6 miles 350·4 yards from the northern entrance, and was completed on October 10, 1903 (Fig. 10).

Strong iron doors were fixed in both headings, 6 miles 517 yards, which could be closed in case of necessity, so as to hold back the water from the hot springs. A very hot spring of 528 gallons per minute, encountered on May 18, 1904, combined with an accident to the water-conduits outside the tunnel at Morel, compelled the miners to retire, and all progress in the advancement of the gallery was arrested. Once more it was prophesied, by those who had failed to realise the determination of the men who had the work in hand, that the tunnel was now impossible, and could not be completed. But Herr Sulzer said the word "impossible" was not in his dictionary, and that the tunnel must be put through.

Just before this cessation of work occurred, the engineers on the Brigue side, who were verifying the axis on a Sunday morning when perfect silence reigned in the solitude of the tunnel, heard the drilling machines at work on the Italian side when there still remained 1,094 yards to be perforated. All hopes were now centred on the Italian advance; but although the miners had the great advantage of an ascending gradient of 7 per 1,000 (1 in 143) to free them from water by gravitation, the temperature and the hot springs became well-nigh unbearable.

On February 12, 1905, the diaphragm remaining to be pierced was 59·75 yards in thickness; and on the evening of February 23 this had been reduced to 5 yards, an advance of nearly 55 yards in 11 days. A spring of water of 330 gallons per minute and a temperature of 112 °F. were then encountered on the floor of Gallery No. 1 from Iselle. At the same time a signal came from Brigue to the effect that the gauge on the iron door indicated a reduced pressure on the part of the imprisoned water; and arrangements were at once made to allow the escape of the coming flood by Gallery No. 2.

On February 24, at 6 o'clock in the morning, the incoming shift of men, with the officials who intended to assist at the final "holing through," were unfortunately delayed by their train being derailed. This was announced by telephone to the men at work at the face, who at once expressed their willingness to continue their labours. At 7.20 a.m. the final charges were exploded in the roof of the gallery, 9,385 metres from the southern portal, producing an aperture of 8·53 ft. in length and 2·62 ft. in width, Mr. Bacilieri being the only official and engineer actually present. Immediately a large volume of hot water ran out, which took half an hour to escape. The engine pumping in cold water broke down, and all the men had to leave the tunnel, but two of the officials were killed. This meeting of the headings proved the extreme accuracy with which the works had been executed, but it lacked the fervour and delight usual on such occasions: it was a meeting of miners on one side and hot water on the other. The last 245 metres of the gallery had taken nearly six months in execution, owing to the unprecedented difficulties encountered.

Up to the date of the meeting of the galleries, the amount of material excavated was 1,229,500 cubic yards. The total quantity of dynamite used was 1,496 tons, all of which had to be carried from the dynamite-trains up to the working faces on men's backs, with innumerable precautions.

In the year 1905 a most impressive thanksgiving service was held in the middle of the tunnel six miles from each entrance.

Tremendous though the difficulties had been, the great barrier between Italy and Switzerland was successfully pierced: and a new highway between the nations had been created. All this had been accomplished with a comparatively slight loss of life.

It was right and fitting that the men who carried out this colossal work, and representatives of the nations concerned, should acknowledge in this way their indebtedness to Almighty God, without whose blessing all the skill and labour would have been in vain.

On Sunday, April 2, the partners of the contractors' firm, the engineers and officials, and their friends assembled at Brigue Station were conveyed to the middle of the tunnel to the iron door which had done such important service. At the same time those from Iselle arrived at the other side of the door. At the right moment this door was opened by Col. Locher of Zurich, and he was met and embraced amidst the greatest enthusiasm by Dr. Edouard Sulzer and Herr Brandau, the other partners. After these came the Bishop of Sion from Switzerland and the Bishop of Novara from Italy, who also affectionately embraced. Their example was followed by the two bodies of officials and visitors. In the widened portion of the tunnel a dais had been erected, and this ever-to-be-remembered service of thanksgiving was held.

The first train passed through on January 25, 1906, and on May 19 the King of Italy traversed the tunnel in a special train, meeting the President of the Swiss Republic at Brigue. The President returned the compliment by travelling with the King to Domo d'Ossola. The King of England sent a telegram of hearty congratulation.

On May 30 three long passenger trains, containing 850 guests, including the Swiss President, M. Forrer, and his Ministers, made the passage of the tunnel, having been received at all the stations along the route with great rejoicings. On the platform at Brigue there was an old Simplon Pass diligence and two snow-sleighs for luggage, with a large placard over them bearing the inscription "*Morituri te salutant!*"

The final measurements of the tunnel, showing the extraordinary accuracy attained by Professor Rosenmund at the completion of this great work, must not be omitted.

The divergence of the centre lines from Brigue to Iselle, $12\frac{1}{4}$ miles, was $3\frac{2}{3}$ inches; the difference in levels was $3\frac{1}{2}$ inches; and the total length was found to be 31 inches, less than anticipated.

CHAPTER VIII

SOUTH AFRICA: THE BULUWAYO RAILWAY; BRIDGING THE VICTORIA FALLS (1895–1905)

It was my father, Sir Charles Fox, who, as Consulting Engineer to the Government of Cape Colony from 1864 to 1867, designed and carried out the first railway in that part of the Empire, from Cape Town to Wellington, with a branch (opened in 1890) to Wynberg on the other side of Table Mountain. And it was in connection with this railway that the father of the late Mr. George Pauling went out originally to South Africa. This name is well known and respected by the natives throughout Rhodesia for the kindly way in which they are treated by that firm and its representatives, amongst whom I may mention Mr. Buchan, Mr. Lawley, and the Resident Engineer, Mr. Roy. One great attraction for the natives is that cold-storage wagons loaded with fresh meat are run up to the railhead for feeding the workmen. The excellence of these arrangements, and the great energy with which the work is carried out, were the important factors in the successful construction of the railway to Buluwayo and beyond.

Another name which must stand at the head of the history of the South African railways is that of Sir Charles Metcalfe, Bart.—an intimate friend of Cecil Rhodes in their undergraduate days at Oxford. My brother Douglas and I were associated with Sir Charles for many happy and successful years in the development of railways both in England and in Africa. Sir Charles Metcalfe possesses, to a remarkable degree, an intuitive knowledge of the course which any projected railway should take.

He walks over the route, even when it extends to hundreds of miles, and lays down on a map the direction the railway should take. This is then carefully adjusted by level and theodolite, and the result is found to agree most remarkably with the route which he selected.

In the year 1897 orders were given for the construction of a railway from Vryburg to Kimberley, and from Bechuanaland to Buluwayo, the Directors of the Company being Mr. Rhodes, Mr. Beit, Mr. Maguire, and Mr. Shiels. The gauge was fixed at 3 ft. 6 in. so as eventually to join with the Egyptian railways of the same width, and thus be prepared for through traffic from Cape to Cairo.[1]

The types of Englishmen, Scotsmen, and Irishmen we met with in Rhodesia could hardly be excelled in any part of the world: fine, manly, kind-hearted, well-educated men, evidently determined not only to uphold the Imperial flag, but to be an honour and a credit to the old country.

[1] It is a subject for real regret that the gauge for the Uganda railway was fixed by the Indian Government, under whose control it was constructed, at one metre, or 3 ft. $3\frac{3}{8}$ in. This mistake will eventually have to be rectified at very great cost.

The difficulty of getting supplies into the country was great, owing to the ravages of rinderpest amongst the cattle and horses, which were threatening the existence both of British settlers and natives. Hundreds of wagons on their way up country had to be abandoned, with their contents, in consequence of the oxen having died. Then came war and famine, bringing in their train terrible trials and hardships. It was a matter of surprise to all of us how the British community in Rhodesia ever lived to tell the tale.

But Rhodes, with his wonderful foresight and indefatigable energy, determined to get the railway through at the earliest moment to save the situation. His resolve, manfully aided by engineers and contractors, resulted in the construction and opening to traffic of 500 miles of railway in 400 working days. This was a feat of which all could be proud. On one day alone, eight miles of rails were laid. Pluck, patience, and perseverance had conquered.

On November 4, 1897, four heavy special trains of the Rhodesia Railway Company, consisting of sleeping- and dining-cars, carrying 800 guests from all parts of the empire, arrived in Buluwayo from Cape Town, a distance of 1,360 miles, and the railway was formally opened by His Excellency the High Commissioner, Sir Alfred Milner, G.C.B., now Lord Milner.

A thing not to be forgotten on this occasion was the voluntary self-effacement of Rhodes, unwilling as he was to introduce any possible element of discord owing to events which had occurred not long before. It was characteristic of the man so to sink himself in his work. He built for the future, rather than for present glory or comfort. A fine saying of his comes to my mind. He had been planting an avenue of oak saplings on his estate at Buluwayo, and a friend remarked to him that no one living would see the trees full grown. Rhodes quietly replied, "I can see the people now, walking up and down under their shade."

In the course of time the railway was extended not only to Salisbury and Beira on the east coast, but to the Wankie Coal-mines, and to the Victoria Falls to the north-west. Thence it was continued to Barotseland and the Great Katanga copper deposits on the north-west, forming a junction with the Belgian railway in the Congo.

From the fine harbour of Lobito on the west coast the railway, under the guidance of the indefatigable and long-visioned Mr. Robert Williams, has since been built for some 400 miles in the Province of Angola, and is about to be pushed forward a further 450 miles to the Congo border, where a junction will be made with the Belgian line. There will then be a through route from Lobito and Benguella, to the Cape and Cairo railway, connecting with Johannesburg and Durban, as well as Cape Town.

An extraordinary disaster befell the surveys of one of the South African railways. As each length of the plan and section for a distance of 40 miles was completed by the engineers on the spot, it was sent by registered post to London. All the drawings duly arrived with the exception of those of the final 40 miles. To save time the plans of this last section were brought to London by one of the chief engineers in charge of the survey. Arriving in London one evening, after months of tinned food, he not unnaturally turned his thoughts to a good dinner, and went to the Holborn Restaurant, telling his cabman to wait outside. After his dinner he fell asleep, and on awaking went out to find his cab. To his dismay he found that the man had driven off ! The police were informed, and every effort was made to find him and the plans, but not a trace was ever discovered of either. The result was that another expedition had to be sent out to resurvey and make fresh plans and sections. The work occupied several months, and involved a further outlay of £4,000, a fairly heavy penalty to pay for an after-dinner nap.

On April 25, 1904, the railway reached the Zambesi River and its wonderful Victoria Falls. Some months earlier Sir Charles Metcalfe had fixed the point of crossing, where the bridge now stands. This was erected by the Cleveland Bridge Company of Darlington, whose representation was Mr. Imbault. The bridge consists of a handsome steel arch in one clear span of 500 ft., with an adjacent span on each side. The height is 400 ft. above the river, and as it would have been impossible to erect scaffolding, the work was carried out by means of two great cantilevers. A photograph (p. 101) is given showing operations in progress.

The first thing to be done, about October 1903, was to connect the two cliffs by some means of transport. A rocket, to which a fine string was attached, was fired across the gorge and after three attempts the string reached the other side. This string enabled a cord to be pulled across, then a wire, and finally a $\frac{5}{8}$-in. steel cable, carried on supports and strained tight. Then by means of a " bo's'n's chair " one person at a time was able to travel from side to side.

The small cable enabled a much stouter steel rope to be fixed in position to carry the electrical " Blondin." This was capable of conveying a load of 10 tons, and as the bridge had been so designed as to have no member of greater weight, the construction of the arch could proceed from both sides of the gorge simultaneously, until the two ends of the cantilevers were within 10 ft. of each other. The gap was to be filled in with special girders, but when it was attempted to drop these into place, they were found to be six inches too long, and would not fit. Needless to say the members of the staff were much disappointed, and they retired to bed that Friday night in considerable anxiety. The day had been one of unbroken tropical sunshine, and this had elongated, by expansion of the steelwork, the two halves of the cantilevers. But providentially, during the night, the wind changed and blew the spray of the Falls on to the work ; and by cooling down, and thus shortening the two halves of the arch, the closing length in the centre was able to be dropped and bolted into its place at 7 a.m. on Saturday morning April 1, 1905, and the bridge was completed : thanks are due to the Cleveland Bridge Company, Mr. G. A. Hobson, Mr. Im Thurn, and others.

A telegram was at once dispatched from Rhodesia to Sir Douglas, in Westminster, saying "Bridge complete," which he duly received on the same Saturday morning at 10 a.m. He re-telegraphed it to me in Switzerland, and I received it at 12 noon on the same day, just as I was starting from Vevey in a long special train filled with guests on their way to the Simplon Tunnel, to be present at the connection of the two advance galleries between Switzerland and Italy. These two events, the joining of the great bridge girders in Rhodesia, and the connecting of the tunnel galleries between Italy and Switzerland, had occurred almost simultaneously.

My son, Charles Beresford Fox, was on the engineering staff employed in the erection of the bridge over the River Zambesi, and he it was who crossed for the first time in the bo's'n's chair. During the erection of the bridge he met with a very serious and unusual accident which all but cost him his life. He had found it necessary to climb down to a point on the water's edge which hitherto had never been reached, in order to take certain measurements and photographs. He had descended without serious difficulty, but owing to the overhanging of the cliff he found it impossible to get back without a rope; therefore one was accordingly thrown down to him, and twenty Cape "boys" hung on to it, as he climbed upward hand over hand to within 6 ft. of the top. But the rope had been wetted by the spray, and the men holding it had allowed it to slip imperceptibly little by little through their hands, and it had passed through a large greasy fungus, and my son, after long climbing, grasped this slippery rope in all ignorance. Immediately his grip was gone: he fell head over heels down the face of the precipice a distance of over a hundred feet, and gave himself up for lost, as the sun had set and it was dark. But providentially he was caught in the boughs of a small fig tree, the only tree on the face of the cliff. The Cape boys, so soon as they felt that his weight was not on the rope, bolted to their camp two miles distant, alleging that the presiding spirit of the Falls had taken him for venturing to cross. The only Englishman present, a Mr. Whitten, went after them, and brought them back, made them lower him down the face of the cliff three times before he could find my son; and it was six hours before they landed him at the top. Beresford was seriously injured in arms, legs, and back, but his life was saved, and in a letter to me he said he attributed his escape to the direct intervention of God, as nothing else could have saved him.

I tried for sixteen years to find Whitten, the man who had rescued him, and only heard of him, at last, by a curious chance. Next door to my house, Alyn Bank, lived the late Mr. Lockwood, the well-known publisher. His son Captain Lockwood was in Rhodesia in 1919 on Government business, and had to cycle across the veld to Victoria Falls, a distance of 300 miles. Hospitality had to be offered to travellers by the British colonists in this very sparsely populated district, and one night an English blacksmith gave Captain Lockwood shelter and a welcome. In a letter to his father Captain Lockwood said that he observed on his host's table a very handsome presentation clock, and asking for its history, Whitten said that it was given him for pulling a man out of the Victoria Falls gorge during the construction of the bridge. Captain Lockwood adds: "I immediately remembered Sir Francis Fox's story of how his son had fallen down and been pulled out, and of course this was the same man."

At last I was enabled to write to Mr. Whitten, and thank him for saving my son's life; to which he replied, April 4, 1920:

"As to what I did at the Falls for your son, it is, or was, only what any Englishman would have done under the circumstances, and I thank you for your kind reminder."

The accident occurred January 11, 1904.

A high steel viaduct at Vanstaden near Port Elizabeth in Cape Colony, the design and construction of which we engineered, illustrates the most rapid and the easiest method for crossing deep ravines. It is 270 ft. in height, the gauge of the railway being 3 ft. 6 in., and it was completed in 1905.

Our firm, in conjunction with Sir Charles Metcalfe, also engineered the railway from Blantyre in Nyassaland, to Chinde and Port Herald. This has now been extended 165 miles south to the Zambesi, connecting up with the Port of Beira, and the Rhodesian Railway system. It forms a very important line of communication not only with South Africa, but also between the east and west coasts.

CHAPTER IX

CANADIAN RAILWAYS

Canada is a delightful country and embraces every description of scenery. Vast plains, high and snow-capped mountains, lakes and rivers, intense cold in winter, great heat in summer: all these features have to be considered, and dealt with by the thoughtful engineer.

Locomotives must be capable of resisting the lowest, as well as the highest temperature; and suitable and comfortable protection must be given to the driver and fireman against extreme heat and extreme cold. I have seen the pilot engine, one of the heaviest engines built, fitted with a "cow-catcher" or snow-plough in front, running a few miles in advance of the mail and sleeping-car train, in order to clear the rails, on a pitch-dark night in an intense blizzard. When this engine runs into Sherbrooke Station, between Montreal and New York, the snow is frequently piled up on the top of the boiler, and a mass of heavy icicles hangs all the way along it from the footplate and engine frame, and even the ashpan under the furnace is blocked with solid ice to such an extent as to stop the draught. The fireman has to crawl under the locomotive, to cut out with hammer and chisel the blocks of ice which have formed, before the engine can proceed on its journey.

In Canadian engines the steam and oil pipes have to be placed inside other pipes of larger diameter, the annular space between them being kept warm by a continual flow of steam from the boiler.

During the winter the road bed is frozen so completely, that the necessary packing and lifting of the rails by the platelayers cannot be done in the ordinary manner. Thin hardwood wedges known as "shims" are therefore driven in, between the rail and sleepers, in order to keep a smooth surface on the rails. The Toronto Grey and Bruce, and the Toronto and Nipissing Railways, some 400 miles in length, both of which now form part of the Main Trunk lines in Ontario, and for which Sir Douglas Fox gave important evidence in the Parliament House at Ottawa, were constructed under the supervision of our firm, with Mr. Edmund Wragge, of Toronto, our able representative in Canada, in charge of the Works. At that time these lines ran through virgin forest, and had to be protected against both prairie and forest fires. This was done by clearing the ground of all timber and undergrowth for a width of 100 ft. on each side, so that trees falling or blown down would not obstruct the railway. Even so on one of my visits, when the forest on both sides of the line was on fire and in full blaze, we had to run the locomotive with our heads enveloped in our coats, through the sparks, hot air, and even flames.

In spite of all our precautions the railway for a considerable distance was destroyed. On this particular section the line crossed a morass which in winter was a swamp, but in summer a dried up and inflammable deposit of peat. The great fire

QUEBEC CENTRAL RAILWAY TO THE PORT OF GASPÉ.

A long bridge being erected across a wide river. The piers were constructed during the summer; and during the winter the scaffolding was built on the surface of the ice for the erection of the steelwork.

THE VICTORIA FALLS BRIDGE OVER THE RIVER ZAMBESI IN COURSE OF CONSTRUCTION.

The span of the great arch 500 ft., height above the river 400 ft., the bridge was constructed by the cantilever system, from the two sides. A large net was suspended to give confidence to the workmen.

being fanned by a gale of wind, the flames crept along the surface of the clearing and reached the embankment, which was 12 ft. in height and of peat, of which material the embankments were necessarily made. It was soon alight, the sleepers burnt, and the rails almost calcined. Under the action of the intense heat, the latter had become quite white, and were twisted and contorted into all manner of shapes, looking like tangled cotton in the debris.

This particular fire had swept on for 70 miles, engulfing settlers with their families and live stock in the flames.

We were at one time instructed to make a rapid survey of a projected railway in Labrador, 500 miles in length, to reach an open port on Baffin's Bay. This would have been an interesting enterprise, but we had to report that it was at that date premature.

A photograph is given of another railway we engineered in the province of Quebec. This will serve to show how works are carried out in a severe Canadian winter. Everything had to be done with the greatest possible speed. The temporary trestle work for the construction of the steel bridge was erected on the frozen surface of a wide river. The actual foundations had already been put in during the previous summer.

CHAPTER X

SOME NOTES ON HEAVY EARTHWORK, AND THE PANAMA CANAL

DURING a career of over sixty-three years as railway engineer, it has been my lot to have to deal with cuttings of great depth and embankments of great height, and it may be desirable to place on record the experience gained by such work.

The highest railway embankment which I have had to construct was exactly 100 ft. from the level of the stream passing beneath the embankment, up to the level of the rails.

The deepest cutting which I have had to deal with was one of 80 ft. in very slippery clay of the Blue Lias. The length of this cutting was just over one mile, and the precautionary methods which were adopted, prevented the occurrence of even the smallest slip.

The angle of repose of clay or sand is often the cause of trouble, for the simple reason that this angle varies almost from day to day according to the different conditions of weather, or drainage, or vibration. In addition to the "friction" between the particles of the material there is also the element of what has been well and popularly called "stiction." In more scientific language, these two elements of static and dynamic friction, or "friction of rest," and "friction of motion," should be utilised to the full, and every possible effort should be made to prevent any initial movement taking place. Should such movement occur, then the value of "stiction" is at once lost, and trouble is sure to follow immediately in the flattening out of the angle of repose.

There is a certain cutting in the neighbourhood of London in which the slopes were at the outset left at too steep an angle, with the result that movement began and continued for over fifty years, until at last all semblance to a cutting had gone. Instead of being what is known as 2 to 1 (that is, for each two feet horizontal the slope rises one foot) the two sides of the cutting have attained a slope of 12 to 1, and to-day have the appearance of almost level pasture fields.

It is an axiom accepted by engineers of experience in earthwork, that the first thing to be done is to secure good drainage; when the work is half done, again to drain; and at the finish the last operation is to drain. In other words, every possible precaution should be taken to prevent water getting into the slopes.

After the question of drainage, the two most important points requiring attention are:

(1) The avoidance and prevention of even the smallest inclination to slip, and

(2) The prevention of "creep"—i.e. the rising of the bottom of a cutting due to pressure from below.

In the case of the eighty-foot cutting referred to, we were aware that in the years 1832 to 1837 the cuttings on an adjacent main-line railway running through exactly the same geological formation had been made with original slopes of 1½ to 1. There had been no such work in the neighbourhood before, so that the engineers of that date had no previous experience to guide them. The slope they allowed proved to be too steep, with the result that every cutting and every embankment on that railway has, since that date, slipped to a very serious extent. Thanks,

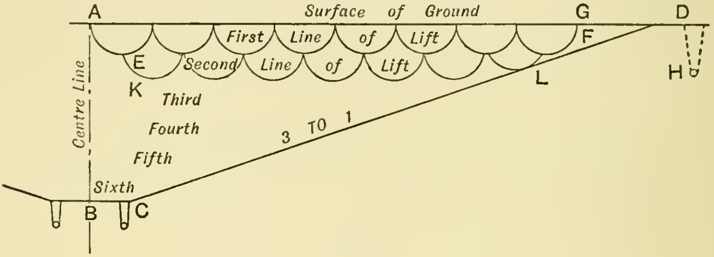


Fig. 11.

AB = The centre line of cutting.
AD = The original surface of the ground.
CD = The surface of the slope to be attained.
EF = Bottom of First Cut of "Shovel" showing radius of digger. The curved lines represent the sweep of the digger.

however, to the experience thus obtained, we decided that nothing steeper than 3 to 1 was to be permitted on the new cutting and the necessary width of land was consequently acquired.

This very important point having been decided, the next question was the method to be adopted for carrying out the excavation (see Fig. 11).

The work would be done with steam shovels or diggers with a depth of cut of about 14 to 15 ft., the whole width of the cutting to be removed before starting on the second lift.

The triangle GFD was removed by hand and then taken away by the "digger" or "steam navvy," care being taken not to encroach upon the future slope CD.

Meanwhile a deep intercepting drain H was made for the purpose of catching any water which might by possibility get down the slope, and at the same time the slope FD was carefully trimmed to prevent the lodgment of any little pool or puddle. It was then soiled and sown with grass.

When the first lift was finished the second one

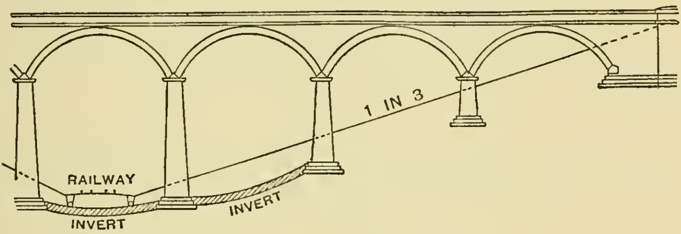


FIG. 12.

KL was taken in hand and treated in a similar manner, and the same method was continued to the bottom of the cutting, where drains of ample capacity were provided to keep the earth below the railway always dry.

In consequence of all these precautions, no slip of any kind occurred. Moreover the removal of the great mass of material enclosed in the triangle ABD had so lightened the pressure on the subsoil below, CD, that there was no tendency to produce "creep" or the lifting of the bottom. It was, however, necessary to provide heavy and substantial brick bridges to carry public roads across the cutting. These bridges (Fig. 12) were 70 to 80 ft. in height and between 30 and 40 ft. in width between the parapets, and as the load on the foundations was considerable it was deemed desirable to build inverted arches of masonry or concrete under the three highest spans so as to render "creep" impossible. As a result, both creep and "slip" were entirely avoided.

Fig. 13 explains the method of constructing the hundred-foot embankment.

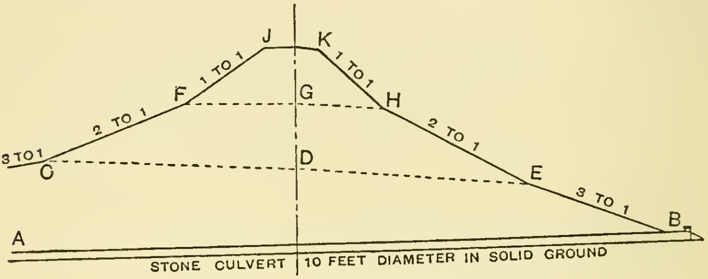


Fig. 13.

AB is the original surface on which the embankment had to stand: this was well drained by means of deep open rubble channels, practically forming watercourses, in addition to a culvert 10 ft. in diameter under the greatest depth of bank, and built in the solid ground. The bank was divided into three heights; the bottom third was tipped to a slope on both sides of 3 to 1, the centre being kept high at D, in order to give a rounded surface for drainage to the sides and prevent the lodgment of water in the middle of the embankment. The next one-third up to FGH was made with slopes of 2 to 1, the surface FGH being again well rounded. The highest one-third up to the top was tipped to slopes of 1 to 1; it was made with excellent dry material of furnace ashes, or burnt shale, which was available near at hand. The surface JK was again so formed as to throw off any water to the sides. The slopes were then soiled and sown with grass.

At another place a most unexpected difficulty was encountered. A fine viaduct built of substantial brick in cement, some 80 ft. in height, 32 ft. in width at rail level, and nearly a quarter of a mile in length, had just been completed. Its foundations had been carried down to a considerable depth in hard Blue Lias Clay, and as a precaution, a boring was put down to a further 30 to 40 ft. which proved the similarity and continuance of the same good solid clay, good enough, as the inspector reported, "to carry a cathedral." Within a month of its completion the whole hillside above the railway began to move and slip down, carrying with it the viaduct. Immediate steps had to be taken to stop the movement, although the cause was entirely unknown.

Large excavations 30 ft. square were quickly sunk, on the lower side of the viaduct. These revealed a thin smooth bed in the clay some 20 ft. below the surface, and of no greater thickness than a sheet of writing paper. This slippery bed was of a bright metallic lustre, like a metal dish-cover, and had no doubt become polished by the great weight and heat produced by the friction of the moving mass.

The excavations were quickly taken down some distance below the unstable bed and were filled in with quick-setting cement concrete. They acted like large "dowels" pinning the moving mass to the strata below, and the motion was satisfactorily arrested.

The cuttings in the Panama Canal have been on a far larger scale than the operation I have just described. But the same principles hold good of the larger as of the smaller earthworks. I have not had the good fortune to visit the Canal, but from information and photographs so kindly supplied to me,[1] and from descriptions I have received from several friends who have been there, I am able to realise, almost too vividly, the well-nigh insuperable difficulties with which the engineer-in-chief had to contend. These difficulties were, I should believe, a legacy he has taken over from the original Company, who, in their anxiety to get a communication through at the earliest possible moment, drove a narrow and deep pilot heading through the hill and started these slips, failing at the same time to provide efficient drainage.

The slopes throughout the Culebra cutting are far too steep, and have resulted both in disastrous movements of the material in the form of slips, and also in "creep," which has lifted the bed of the Canal. This threatens to continue until the superincumbent mass for a width of some thousands of yards on the sides of the channel shall have been removed and equilibrium restored.

[1] I desire to take this opportunity of tendering my thanks to Major-General Goethals, U.S. Army, the Governor and engineer of the Panama Canal, for his kindness and courtesy in furnishing me with his reports upon, and photographs of, this great work.

It has been asserted that if the Canal had been constructed at the low level, without locks, these difficulties would never have arisen. This is quite untrue. The cutting would have been 80 ft. deeper, the width would have been correspondingly greater and the load upon the strata larger.

Nor did the hope, which was expressed by many, that so soon as water was admitted to the Canal, its weight would keep the bottom down, rest on a better foundation. Forty feet of water would not restore equilibrium where 350 ft. of earthwork had been removed.

Efficient drainage of the side slopes, now that they are so thoroughly broken up, is impossible unless a fresh start were made far away from the canal. In such a wet climate as Panama, drainage is rendered most difficult, but I venture to think that excavation by "hydraulicing" is most undesirable as it cannot fail to saturate and loosen the ground for considerable depths below the surface.

Had the excavations from the beginning been carried out on the principles I have described; had proper slopes been provided, and efficient drainage installed, the difficulties, and probably the cost, and certainly the disappointment would have been far less.

CHAPTER XI

THE CHANNEL TUNNEL

In this chapter I propose to deal chiefly with the geographical aspects of the Channel Tunnel, but I must first say something about the geological and engineering problems.

Geological considerations come first. Upon these primarily depend the success or failure of the undertaking.[1] The problem is very different from that of tunnelling between Great Britain and Ireland, where the difficulties are, I think, insurmountable owing to the fact that such a tunnel would have to be about 600 ft. below the level of the Irish Sea. For the construction of the Channel Tunnel the conditions would be much more favourable. It is an established fact that England and the Continent at one time formed continuous land, and that the geological strata on both sides of the Channel are identical. The beds, their thickness, the dip, the formation, are similar in all respects; and the outcrops of the various strata have been carefully and correctly surveyed by several thousand soundings and borings, made over the entire distance between England and France.

In bygone geological ages a great river flowed

[1] Based on the paper read by the author before the Royal Geographical Society, April 23, 1917, and published in their proceedings *The Geographical Journal* for August 1917.

along the line of what is now the Channel. On the Admiralty chart there will be found a very remarkable ravine north of Guernsey, called the "Hurd Deep" or "La Grande Fosse." This ravine in the sea-bed extends for a distance, from east to west, of about 75 miles with an approximate width of 3 miles. The depth of the Channel north and south of "La Grande Fosse" averages from 34 to 35 fathoms, but the soundings in the ravine itself rapidly increase until they reach 110 fathoms. This ravine is nothing less than the remains of the channel of the great river which millions of years ago flowed between the two countries, and eventually helped to bring about their separation.

The white chalk cliffs of England, and of France in the neighbourhood of Cape Grisnez, rest upon a lower bed of Grey Chalk, "the Cenomanian," some 200 ft. in thickness; and this in its turn lies upon a solid bed of Gault. Both beds are very suitable for tunnel construction; for they are composed of a mixed material very similar and in close analogy to that employed in the manufacture of Portland cement, almost if not wholly impervious to water. The electrical tube railways of London owe their existence to the fine deposit of another impervious material, the Blue London Clay, an ideal formation in which to construct tunnels. In the districts where tube railways are conspicuous by their absence, such as the south-eastern portions of the Metropolis, their non-existence is chiefly due to the absence of London Clay.

The grey chalk was doubtless at one time white chalk, and was then water-bearing. But from some undefined cause the bed became saturated with liquefied clay, which percolated into it and "choked the filter," rendering it watertight.

In deciding upon the actual route of the Channel Tunnel the one great precaution to be taken is to keep the work well within the thickness of the Grey Chalk. But as the line may, near the two coasts, have for a short distance to run out of this bed, it is so arranged as there to enter the Gault, which is an equally good and watertight material. Owing to the observance of these precautions the tunnel will not make a "bee line" from England to France, but the slight sinuosity or curve introduced is otherwise of no importance.

In the Channel above the sea-bed the maximum depth of water would be from 160 to 180 ft. We shall be asked to leave undisturbed a cover of chalk over the roof of the structure sufficient to guard against any possible hostile contingency. This solid protection has been fixed at a minimum of 100 ft.

The tunnel would consist of two tubes as described in Chapter VII in the case of the great Simplon Tunnel ($12\frac{1}{4}$ miles in length) in the Alps.

The reasons for adopting twin tunnels are numerous. Ventilation, drainage, repairs to the structure and permanent way during traffic, risk of collision, a possible derailment—all these considerations are in favour of two tunnels rather than one. But one special reason for making the Alpine tunnel two-fold was the reduction of pressure on the arch and side walls.

There, 7,000 ft. vertical of material exists above the tunnels. This great load will not, however, have to be provided for, beneath the Channel.

It is proposed to perform the work of excavation by revolving cutters, fixed in Greathead shields. Under this system a rapid rate of advance will be attained, and the debris will be moved from the "face" by high-speed endless belts.

These will be so arranged as to deliver their load direct into the wagons without shovelling or manual labour.

A proposal has been made, that in order to shorten the period of construction, the chalk excavated should be crushed by the excavating machinery, and "slurryfied" into a creamy condition, as is already done in cement works; this "cream" would be pumped into pipes of suitable diameter and delivered on to certain land at the top of the shafts. It is estimated that by adopting this and other improvements, the tunnel could be driven from England to France in three to four years.

As the work will be carried on by electrically driven machinery, the volume of air required for ventilation will be greatly reduced, and arrangements will be made so that excavation and other operations can be carried on simultaneously at many points, thus abbreviating the period required for construction. This will be done by the method of "breaking up into full section." A small heading, 12 ft. wide and 7 ft. high, is first driven along the line of the future tunnel. At various points on this heading the work of "breaking up," or excavating to the full diameter of the tunnel, can then proceed simultaneously.

The diameter of each tube would be 18 ft., in order to accommodate main-line rolling stock. At intervals of 200 yards along the entire length, oblique cross tunnels will be made. These cross tunnels will not only enable empty wagons to be brought in by one line, while full wagons are dispatched on the other during construction, but will also make it possible to install an excellent system of ventilation. Foul air should be considered as a slur on the management, unfair to the workmen, and injurious to the progress of the work, as well as an unnecessary expense to the company. In the Simplon Tunnel a very large volume of fresh air was always provided, even at the most distant places at which operations were proceeding.

The workmen will be conveyed to their various duties, and brought out again at the end of their shift, by electrical trains. It is anticipated that, in spite of the fact that no work will be permitted on Sundays, except for ventilation, pumping, and urgent repair, the daily rate of progress will be greater than has ever been attained before in any tunnel, and this could be worked, ventilated, and pumped by electricity supplied from a power-station in Kent, possibly 10 miles inland. The problem of ventilation when regular traffic is running will consequently be comparatively simple, since no coal will be burnt on the railway.

The great argument against the building of a Channel Tunnel has always been a military objection. It is feared that it might be used by an invading enemy. But the tunnel would be maintained under the authority of the War Office; and furthermore a dip would be provided in the level of the rails, forming a "water-lock"—so that in an emergency the tunnel could be filled with water from floor to roof for a length of one mile. This would also be under the control of the commandants of Dover Castle and the neighbouring forts. While this water would not injure the tunnel works, it could only be pumped out by the energy developed at the power station inland. At the English end, entrance and exit of both tunnels would be under the gunfire of all the forts and of vessels in the naval harbour of Dover.

The gauges of the English and French railways are very similar. During the Great War hundreds of the largest English and Scottish locomotives and thousands of trucks ran in regular traffic on French railways. Trains would therefore be run direct from London to Paris in less than six hours, and could, if necessary, travel at a "headway" or interval of not more than five to ten minutes.

Doubtless in course of time more than two pairs of rails will be required to deal with the enormous volume of traffic which must inevitably develop in each direction. It should be remembered that, owing to their dislike of the Channel crossing, our Continental neighbours never go on shipboard if they can avoid it. The pre-war traffic from *all* Continental ports to England and *vice versa* did not exceed 1,600,000 passengers a year;

whereas 4,000,000 travelled between France and Belgium and another 4,000,000 between France and Germany. Baron Emile d'Erlanger, Chairman of the Channel Tunnel Company, confidently estimates that the Anglo-Continental traffic, not only of passengers, but also of perishable goods requiring prompt delivery, will, as the result of the opening of a submarine railway, double or treble itself. He believes the financial return upon the capital expended will be highly satisfactory.

It must not be forgotten that the tunnel will require no terminal stations with expensive staffs, nor will the Company have to provide locomotives and rolling stock, as all these will be supplied by the main-line British and French systems. The Tunnel Company would simply be required to construct the works, operate the pumping and ventilation machinery, maintain the permanent way, and keep the signalling and telegraphic equipment in order.

Every one can now realise how enormous the value of such a tunnel would have been to us during the Great War. Many lives would have been saved, and the sufferings of sick and wounded would have been vastly reduced. But that is only the beginning of what it would have meant to us. Delay in the transport of troops and war material, the waste of ships and energy in guarding the passage of reinforcements, the loss of many ships from submarine attacks—all this would have been minimised. Nor must we fail to take into account the immense reduction that would have been possible in the army of dock labourers at the Channel ports of England and France. Indeed the advantage we should have gained by its existence is beyond computation. Certainly the entire cost of this great and desirable work would have been defrayed several times over. Possibly the war itself might have been shortened. Against this we may set the fact that a tunnel constructed at the present time, with our increased knowledge of the problems involved, will be superior in several important respects to what it would have been twenty-five years ago.

Much more could be said both upon the geological and the engineering aspects of the tunnel. But I wish particularly to draw attention to what may be loosely called the geographical consequences: these will to some extent be prevented by the extraordinary difference of gauges on the various railways of the world—varying from 5 ft. 6 in. to 2 ft.[1] Probably many of these

[1] The following are the chief gauges which may at some future date be connected:

RAILWAY GAUGES

In Great Britain = 4 ft. 8½ in.

In Ireland = 5 ft. 3 in.

In U.S.A. = 4 ft. 8½ in.

The 4 ft. 8½ in. gauge is also used in Canada, France, Germany, Netherlands, Belgium, Denmark, Austria, Hungary, Italy, Switzerland, Sweden, and European Turkey.

In India = 2 ft. 6 in.; 3 ft. 3⅜ in. and 5 ft. 6 in.

In South Africa = 3 ft. 6 in.

In Egypt = 4 ft. 8½ and 3 ft. 6 in.

In Ceylon = 5 ft. 6 in.

In Russia = 5 ft. 0 in.

In Spain and Portugal = 5 ft. 6 in.

In Asia Minor = 4 ft. 8½ in. and 3 ft. 5½ in.

A single track of 4 ft. 8½ in. gauge requires 12 ft. of roadway a double track requires 23 ft. of roadway.

will be altered to what may become practically the standard gauge. Where alteration is not made, a transhipment of passengers and goods, say once in a thousand miles, will be unavoidable. One, however, cannot forget the delay and discomfort caused by the difference in gauge already existing at the Russian Frontier stations on arriving from France, Germany, or Turkey.

So soon as trains can pass under the Channel they will be able to traverse France, Belgium, Holland, Spain, Italy, Germany, Austria-Hungary, and Turkey as far as Constantinople without any difficulty as to gauge or minimum structures. The Orient Express connection formerly left London at 9 a.m., an inconvenient hour for many: when the Channel tunnel is an accomplished fact it will be able to leave at noon and still depart from Paris at the usual hour. It will pass through Germany and Austria-Hungary to Bucharest, or through Bulgaria to Constantinople. A quarter of an hour later a train will leave Charing Cross as the Nord Express for Brussels, Berlin, and Konigsberg to Petrograd, and for Warsaw, Minsk, and Moscow. At Moscow it will at some future date we hope connect with the Siberian Railway Express to the Far East and provide communication also with the many charming and healthy watering-places in the Southern Crimea, where great developments are taking place. At further intervals of a quarter of an hour the Rome express will leave for Paris, the Riviera, Rome *via* Turin and Milan, and Brindisi: followed by the Sud Express to Paris, Bordeaux, Madrid, Algeria on the one hand, or to Lisbon on the other. There will be direct communication not only with Belgium, Holland, and Denmark, but also with Finland, Sweden, and Norway *via* Tornea.

This wonderful network of railways feeds Europe, but far greater developments are possible. From Petrograd and Moscow trains already run through the Ural Mountains, traversing Siberia and eventually reaching Pekin and the Chinese system of railways. Vladivostok need be no more than thirteen days from London. Some fifteen years ago a great extension of the Siberian Railway was advocated. It was to be called "The Trans-Alaska Siberian Railway." Starting from the Trans-Siberian Railway at Irkutsk, and skirting the north shore of Lake Baikal, it was to run to East Cape, the most easterly point in Asia, at Behring Strait. At the same time an extension of the Canadian and American system of railways was to be built from Vancouver to Dawson City, going due west to Cape Prince of Wales, the most westerly point of the North American Continent. There would still remain a gap in railway communication at Behring Strait. Plans and estimates of a tunnel beneath this strait were talked of. Two islands exist on the centre line of the projected tunnel which would enable construction to proceed from six different points simultaneously. The total length of the tunnel was said to be 38 miles; and indeed well-known gazetteers like Lippincott and Chisholm give 36 miles as the width of the strait. But the Admiralty chart and Findlay's *Northern Pacific* make it about 56 miles instead of 36. A tunnel under Behring Strait is therefore impracticable, at least to present ideas of engineering.

The western terminus of the Baghdad Railway (4 ft. $8\frac{1}{2}$ in. gauge) is at Haidar Pasha, near Scutari on the Bosphorus, where some means of communication will be required to connect what is now Turkey in Europe with Turkey in Asia. The details of this necessary work will demand much consideration: for although a tunnel, a bridge, or a ferry has each its own advocates, there are many points requiring to be carefully weighed. The last-named proposal, a ferry, is free from the all-important objections to a Channel ferry. The Bosphorus, unlike the Channel, knows no tide and no stormy weather. The Baghdad Railway thence traverses Asia Minor and the Taurus Mountains. It then passes to the north of the Gulf of Alexandretta, with its fine harbour, through Killis (the junction for the Syrian Railway and Mecca), towards Mosul and Baghdad. The development of Mesopotamia as one of the great granaries of the world, when all the necessary barrages and dams, the drainage and irrigation works are in operation, will inevitably be accelerated by the railways ; and access will be given to the British oil pipe-line in Persia. The railway will have to be extended to Basra and Koweit ; passing round the northern end of the Persian Gulf it will reach Karachi, and thus get into touch with the whole of the Indian system of railways. At Killis, already mentioned, is the junction of the Baghdad Railway with the existing

Aleppo-Hamah-Homs of the same gauge: also with the Hedjaz Railway (gauge 3 ft. 5·34 in. or 1·05 metre), which connects Damascus and Medina. Other junctions will be (or are already) made with the railway from Jaffa to Jerusalem (1·00 metre gauge)—which would have to be widened—also with the Beirut and Damascus Railway (1·05 metre gauge). From the Aleppo line at Rapak a direct line to Cairo exists as far as Beersheba, and from the Suez Canal to Gaza is available. This will be 4 ft. 8½ in. gauge, and from Aleppo to El Kantara on the east bank of the Canal the distance will be 420 miles. The Canal would have to be tunnelled or provided with a lifting bridge or a ferry for connection to be effected with the entire system of Egyptian State railways.

The projected and partly constructed Cape to Cairo Railway would eventually carry on the system to the Victoria Falls, Buluwayo, Johannesburg, and the Cape; and it would follow as a natural corollary that the Uganda Railway, and also the East African and West African lines, would eventually be joined up with it.

I am informed that surveys have been made for a railway from Irkutsk through China to Hong-Kong. Were this to be built the time from London to Hong-Kong would probably not be more than fifteen days, as compared with thirteen to Vladivostok. Singapore could be reached in about the same time if the Indian and Burmese lines were to be connected with those of the Malay States. Either of these routes would very materially reduce the sea passage between England and Australia; and when the transcontinental railway is built the London mails could probably be delivered in Sydney well within thirty days from London.

The war has brought home to the minds of us all the extraordinary development of submarines, with their enormous potentialities for mischief. We may hope that such a war and such an abominable use of submarine warfare will never occur again; but in the interests of the world at large we ought to see to it that communication exists wherever possible by railway, as well as by shipping.

It may seem to us to-day a very remarkable prospect, but it is by no means unlikely that within a comparatively few years travellers from London will be able to reach the most distant places in Europe, the most eastern parts of Asia, North and South Africa, India and China, without leaving the railway systems of the world. In the linking up of the world's railways the Channel tunnel will play an important part. It will stimulate trade as well as travel, and contribute to that growth of international understanding which can alone prevent the repetition of war.

PART II

ANCIENT BUILDINGS

WINCHESTER CATHEDRAL

BUILT

TO THE GLORY OF GOD

1087—1093

PRESERVED BY THE GOODNESS OF GOD

1905—1912

CONSECRATION

ST. SWITHUN'S DAY 1093

THANKSGIVING SERVICE

ST. SWITHUN'S DAY 1912

LAUS DEO

CHAPTER XII

THE RESTORATION OF WINCHESTER CATHEDRAL (1905—JULY 1912)

I DO not propose to describe this magnificent Cathedral, except in so far as this is necessary to explain how the actual collapse of the fabric, at one time regarded as imminent, was prevented.

Winchester Cathedral stands on the site of a Saxon Church. After the Conquest in A.D. 1066, William I made Winchester his capital and placed his treasure house there. In A.D. 1079 the foundation of the great Norman Cathedral was laid by Bishop Walkelin, cousin of the king. The founders in selecting a site had chosen a spot that left nothing to be desired for a good supply of water and of fish, and also for good drainage, but they little dreamt of the difficulties which their choice would entail in future years.

In A.D. 1202 Bishop de Lucy extended the building eastward, pulling down the Norman Lady Chapel, and in its place erecting the charming Early English retro-choir and Lady Chapel as we have them to-day.

Bishop William of Wykeham (A.D. 1367–1404) altered the great Nave from Norman, by encasing the Norman pillars with masonry and adding the fine fan roof in Perpendicular Gothic. One of the most beautiful Chantries was erected to the memory of Bishop Fox; and I ascertained, during the work of restoration, that Bishop Fox had belonged to a collateral branch of my own family.

Every order of architecture from Saxon up to the present time is represented in the Cathedral.

I had been so much impressed with the great utility of the Greathead grouting machine,[1] that for some years I had urged its employment on architects, but with no practical result until I was requested by Dr. Furneaux, the Dean, to accompany Mr., now Sir Thomas Jackson, Bart., R.A., on June 27, 1905, to Winchester. The architects had found very serious subsidences in various parts of the Cathedral, that in the presbytery amounting to nearly 2 ft. 6 in. The outer walls and buttresses had gone seriously out of the perpendicular, while the beautiful groined arches were distorted in form, and disintegrated in character, and alarm had been caused by the fall of some stone from the roof. Sir Thomas Jackson had sunk a trial pit some few yards distant, and had discovered a bed of peat 8 ft. deep below the clay and resting upon a fine solid bed of flints and gravel, into which he had bored to some depth to prove its solidity. An excavation 5 ft. in width was then made adjacent to the south wall, in which, at a depth of about 8 ft. below the turf, the bottom of the masonry foundation was reached. It was discovered that the wall had been built on logs of beechwood, in fact, whole trees placed side by side horizontally (Fig. 14), and these again, in their turn, rested in some places on a

[1] See page 128.

second layer of trees, forming a kind of raft. Some of these timbers were rotten, but others were as sound and good at heart as ever. This was under the Presbytery (A.D. 1202). Under the Norman walls the builders had simply driven in

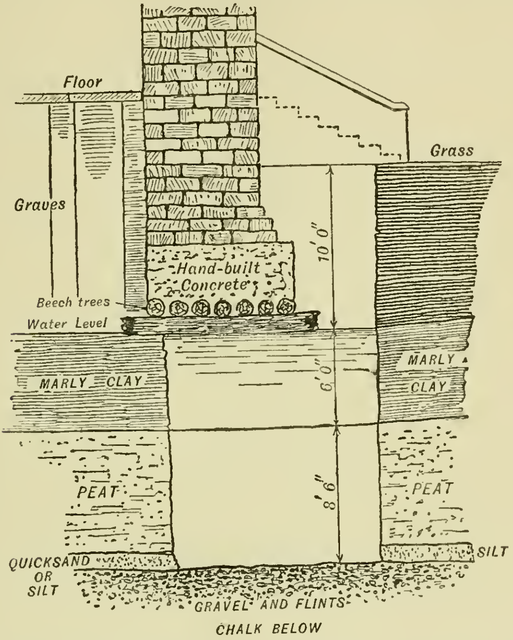


FIG. 14.—WINCHESTER CATHEDRAL: SECTION THROUGH WALL OF PRESBYTERY SHOWING BEECHWOOD UNDER THE FOUNDATIONS AND RELATIVE POSITIONS OF MARLY CLAY, PEAT BED, SILT, AND GRAVEL.

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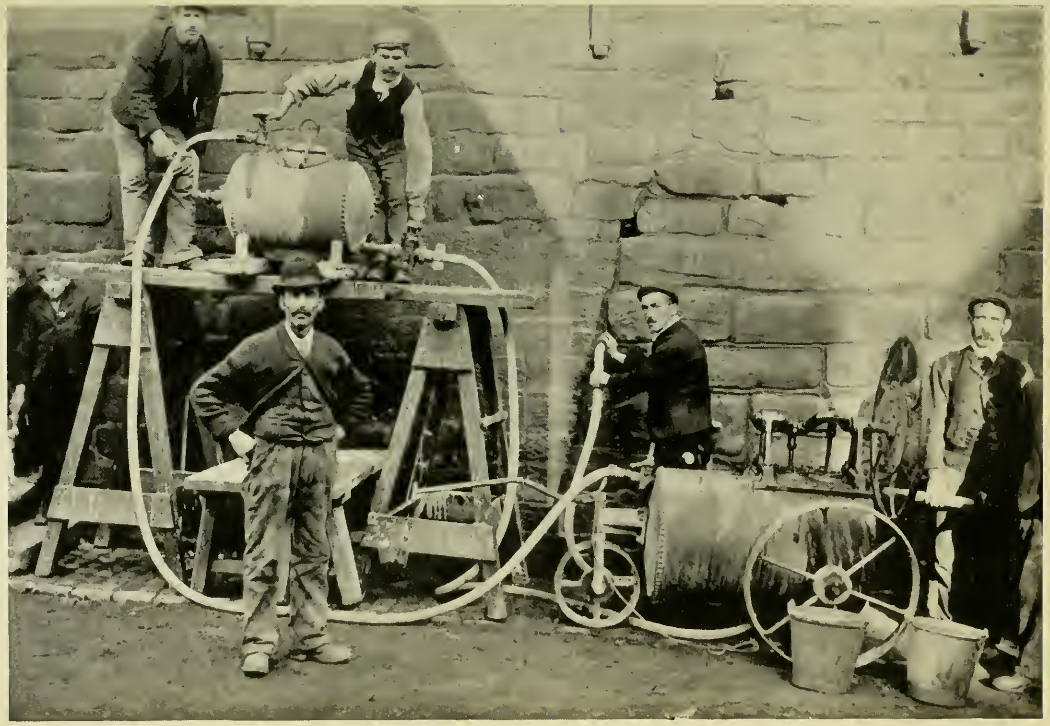
short vertical oak piles, none exceeding 5 or 6 ft. in length.

The problem of strengthening the foundations was, therefore, a very formidable one. For reasons which will appear below, pumping was impossible; compressed air could not be used; screw piles and caissons were considered and rejected; nor could the Cathedral be floated (as was at one time proposed) upon a vast slab of concrete, such a slab would almost certainly have cracked.

How the problem was solved I shall describe shortly; but the first point which we had to consider was the strengthening of the main fabric. I was fortunately able to call the attention of the authorities to a method of repairing old walls at a minimum of cost, and with a maximum of strength. Although many engineers were familiar with the process at that date, it had very seldom been applied, and was not known to circles outside their profession. When a wall cracks, the ordinary remedy is to send for a builder or a mason, and employ him to point up the injury, which he does with mortar and trowel, and he succeeds in producing a result satisfactory to his own pocket, and, for a time, pleasing to his employer's eye. But it should be borne in mind that this pointing goes in for only an inch in depth, and that the injury to the wall is in no degree remedied: the crack, for its entire length, remains a crack, and its tendency to widen is by no means lessened.

In all cases the question of faulty foundations should be examined, but in many instances the upper portions of the work are so weakened and disintegrated that to attempt at the outset to rectify the defects below would bring the whole structure into ruin. To underpin a badly cracked cathedral or church, before securing the fabric itself, is often to court disaster. The Romans were



CHESTER. ANCIENT WALL AND WATER TOWER.
The Greathead grouting machine being applied for the first time in the saving of ancient buildings.

probably aware of the value of "grouting up" their work, but they had not the necessary appliance for doing it effectually; nor had we until within the last forty years, when the late Mr. James Greathead invented the grouting machine for use in the construction of deep tunnels or electric tube railways of London. And here it will be desirable to explain what is meant by the term. If a mixture of cement, sand, and water be made in proper proportion, it is called "grout," and when this is poured, like cream, into the cavities of a wall, the wall is "grouted up." This is, apparently, a very simple process, but it is nevertheless one which requires judgment and care.

The grouting machine consists of an iron receiver or reservoir into which, by means of pumps, air can be forced under any pressure up to 100 lb. to the inch. This receiver is connected by a flexible tube to another portion of the apparatus called the "grouting pan," which is, in fact, a churn furnished with a handle and spindle to which are attached arms or beaters. The proper proportions of cement and water, and in certain cases sand, are then placed inside, the lid screwed down, and the contents churned up into the consistency of cream. This is now ready to be blown into the crack, the mouth of which on either side of the wall has meanwhile been clayed up to prevent the grout from escaping. The compressed air is then admitted to the grouting pan, and as soon as the necessary valve is opened the contents are discharged into the wall, the operation being commenced at the level of the ground.

Having thus at our command an apparatus by which cement can be blown right into the heart of any structure, whereby all the loose particles of stone and the opposite sides of the crack can be agglutinated or, more properly, cemented together, we have the power of repairing injured buildings without being compelled to pull them down. The expense of grouting is very small, and does not generally amount to the one-fifteenth or even one-twentieth part of the cost of pulling down and rebuilding.

As the condition of the fabric was a matter of great urgency, I reported my visit to the Dean on July 5, 1905, and the conclusions at which we had arrived.

We had decided that the proper sequence of remedial measures would be :

(1) Shoring the outside of the building.

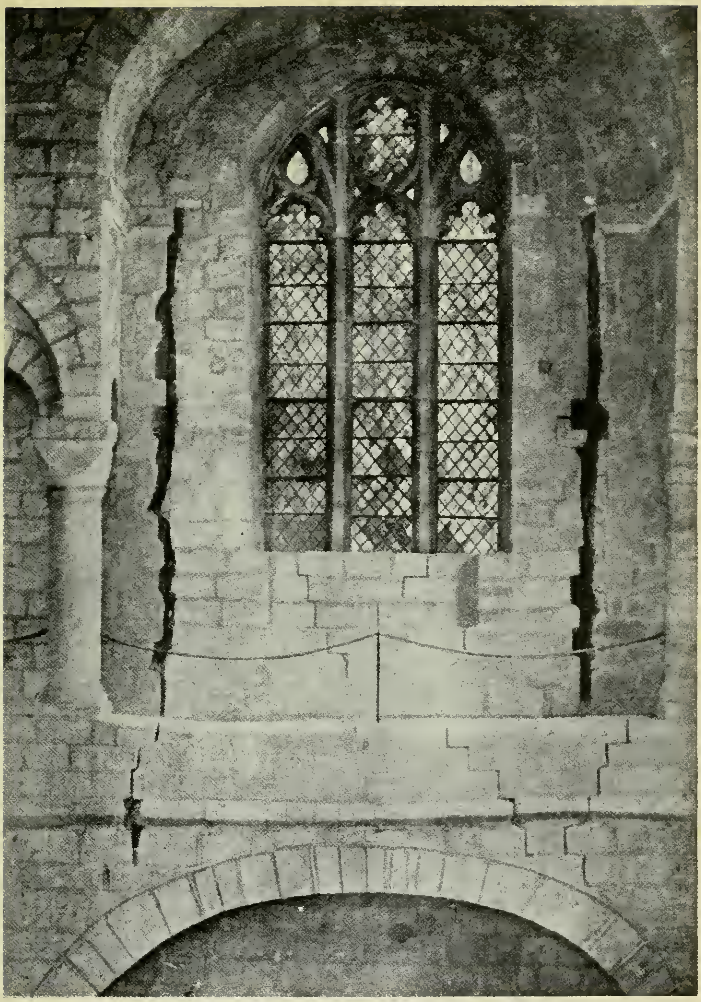
(2) Centring the arched vaulting of the interior to prevent collapse.

(3) Putting in steel tie-rods where these were absolutely necessary.

(4) Grouting with liquid cement under compressed air every portion of the walls into which grout could be forced commencing at the base.

(5) Lastly, underpinning the walls down to the bed of gravel.

We realised that the difficulty of this last operation would be much aggravated by two limitations imposed by the nature of the structure. In consequence of the more or less general disin-



WINCHESTER CATHEDRAL. SOUTH TRANSEPT.

A perpendicular window constructed in the Norman work by William of Wykeham, this in its turn was most seriously cracked, and although the fractures as shown above were about 4 inches in width, they were found to be 12 inches wide beyond the facing—having probably been repaired on two or more occasions.

tegration throughout of the fabric, no vibration must be produced, such as would result from ordinary pile driving, or heavy hammering: and pumping could not be permitted since it would draw away the silt from beneath the whole Cathedral. Fortunately I was accustomed to diving in the dress, otherwise I do not think I should have had the temerity to suggest this expedient. It was only after trying on my drawing board every possible device one after another which I had to abandon as useless and impracticable that I was induced to call in the aid of a diver. The mere idea of diving under the green grass sward of the Close seemed at first absurd, but as it was the only possible means of getting at the foundations, I obtained permission from the Dean and Chapter to try the experiment.

A telegram to Messrs. Siebe & Gorman, the well-known diving firm, brought down two of their most experienced men, and by their aid the excavation, a length of 5 ft., was finished, after which I descended in the dress to examine the bottom. This proved to be a hard flinty gravel, quite excellent, and, as this overlies the chalk, no better foundation could be either secured or desired.

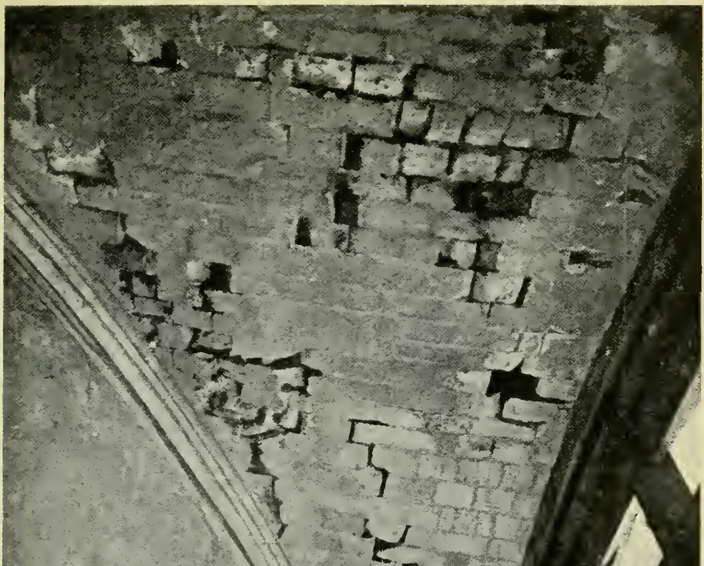
Here I must mention that excellent diver the late W. A. Walker, who in five years and a half did the whole work single-handed. But for his aid it would have been impossible to place this splendid fane on a reliable foundation.

The bed of peat above the gravel had been compressed under the heavy load of the great

Cathedral, probably by 3 to 4 ft., and it was essential that both the peat and the silt should be removed and replaced by cement so that when the work was at an end the fabric should stand on the flint foundation. Each time I visited the work in diving dress I brought up some of the stones as undeniable evidence that in every pit the diver had laid bare the flint.

Only one person could be down under water at a time, and it was with a feeling of distinct loneliness that one crawled along the bottom in pitch-black darkness. But one was conscious of staring with one's eyes wide open, even if nothing could be seen ; and somehow this fact, and the sensation of feeling with the hands for the sides of the excavation, made it possible not only to form a mental picture of the excavation, but to draw an accurate sketch on returning to the surface. The powerful electric light was useless owing to the thickness of the water.

Perhaps a few words may be of interest with reference to the diving. The boots weighed 20 lb. apiece, each having a thick lead sole ; the dress weighed 30 lb. ; the leads on chest and back were 40 lb. each, and the helmet 20 lb., making, with the remainder of the equipment, a total load to be carried of nearly 200 lb. But, notwithstanding all this, the flotation power of the water was so great that a lightly built person going down the ladder, instead of treading on the rungs, had to place his feet beneath them, and pull himself down step by step. The pits were absolutely dark owing to the water being thick with peat



WINCHESTER CATHEDRAL.
Showing the disintegrated condition of the masonry arches over the Presbytery.

and also septic from the graves, and no artificial light was possible; consequently the whole of the work was done, not by sight, but by feeling and with gloves. So soon as the peat was excavated the bottom was covered over with bags filled with concrete, carefully and tightly trodden in, all round; these were then slit open and another layer of bags placed on the top. These again were ripped up, and so on for four courses in all. The whole mass thus became practically a solid rock, and sealed down the flood of water from the gravel, enabling the excavation to be pumped dry. Concreting was then continued, either in bulk or in block, until a considerable height was attained, and upon this, blocks of concrete or brick in cement were carried up and tightly pinned to the underside of the old masonry constituting the original foundations of the Cathedral. When all these excavations or pits were completed, the Cathedral was practically standing on a bed of rock, instead of on compressible peat.

The walls of the Presbytery, Lady Chapel, and particularly the South Transept (which was, still is, and always will be 4 ft. 7 in. out of the perpendicular in a height of 90 ft.), were securely timbered up and strutted before further operations were commenced. The inclination of the South Gable is about one-half that of the Leaning Tower of Pisa.

But before we began to underpin the walls, the grouting machine had to be brought into commission, to deal with the cracks and fissures, some of which were 11 in. wide, in the masonry above. The first step was to force in air under considerable pressure to blow out the accumulated dust of ages, also to dislodge the owls and martins, the rats and mice, and their nests, and in effecting this we dislodged swarms of bees, proving that the masonry was "honeycombed" in more senses than one. Two owls refused to come out, and had consequently to be grouted in.

After blowing in air, water was forced in to wash out the cracks, the effluent coming out black; but as soon as it was clean and colourless we knew that the masonry was in a receptive condition for the cement, which would adhere firmly to the stones. The process of grouting was commenced at the base of the walls in order to obtain the advantage of the hydrostatic pressure of the grout, which ran horizontally in all directions filling every interstice and cavity, and in this way the work proceeded upwards from the ground to the top level of the walls and of the Tower. Some photographs illustrative of the cracks are given.

The extraordinary condition of affairs discovered during the repairs is depicted in the accompanying rough sketch.

It appeared that the weight of the stone groining of the Transept had pushed the main walls of the Nave aisles out of the perpendicular, and consequently William of Wykeham (A.D. 1394) had added buttresses to give support to the original Norman wall. These buttresses were built of fine massive masonry, but unfortunately, so far

WILLIAM A. WALKER.

The expert diver who underpinned Winchester Cathedral single-handed and in pitch darkness.

from giving strength to the wall they did the reverse, owing to their not having been taken down even to the level of the original Norman

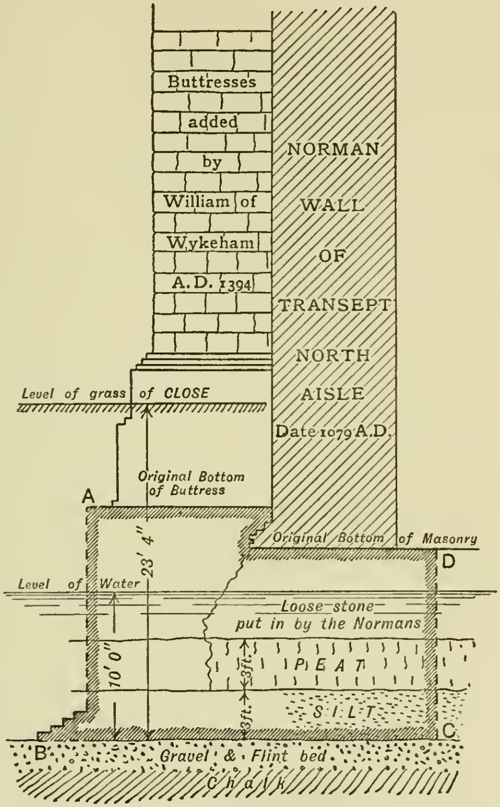


FIG. 15.

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foundation. They therefore hung on to the wall, and increased the danger of collapse.

During the repairs it was found necessary to carry these buttresses down to the hard and firm bed of gravel in the manner shown by the thick dotted line ABCD. This work was executed under water level by the diver Mr. William Walker in 1909, each buttress requiring four pits, all executed in the dark and by feeling.

As the diagram shows, all the buttresses and the adjacent Norman wall were carried down through the loose stones put in by the Norman builders, also through the treacherous peat and silt, and they now rest upon the hard and secure gravel and flint bed overlying the solid chalk.

During the operation for preserving the building a few interesting objects were discovered. In a rat's nest were found fragments of parchment, torn into small pieces; with great care and patience they were pieced together and proved to be an ecclesiastical order for some great religious service held some 700 years ago. We also found a carpenter's measuring rule 36 in. in length—which the owner had dropped behind some wainscoting or carving, probably some 300 to 400 years previously. It had shrunk about half an inch.

A massive piece of polished Purbeck marble weighing 12 cwt. was found buried in rubbish on the south side of the Nave. It had been noticed that one of the monumental slabs in the North Aisle had lost its top member, and that another had been carved in different stone and inferior workmanship to replace the loss. It was therefore a matter of great interest to find that this piece of Purbeck marble was the lost top of the fine monumental slab of Bishop Andemar, half-brother of King Henry III, who died at St. Genevieve's Abbey, Paris, on December 4, A.D.

1260, and whose heart was brought to Winchester on March 20, A.D. 1260–1, and buried in the Cathedral. The recovered fragment bears not only the missing top of the mitre, but also two admirably carved heraldic shields, one representing the royal arms of England, as borne and used by Henry II, and the other the arms of Hugh, Earl of March, the Bishop's father.

In November 1923 an old oak panel in the Cathedral had to be removed (on account of the worm in the wood) and behind it were found an ancient stone seat, a " holy water " stoup, and a parchment document which bears a seal of the date of Edward I. It is the grant of an indulgence for a period of ten days.

The great Festival of Thanksgiving for the saving of the Cathedral began on Sunday, July 14, 1912. The Dean of Winchester, Dr. Furneaux, who, as the moving spirit in the work of preservation, had borne a heavy burden of responsibility, preached the sermon. It was an admirable summing up of seven years' effort and anxiety crowned with success. The evident emotion of the preacher intensified the impressive solemnity pervading the whole service.

The entire cost of the work—£114,000—had been defrayed when the King and Queen visited Winchester on St. Swithun's Day, Monday, July 15, 1912. After being received by the Mayor and civic authorities they reached the Cathedral at 2.30 p.m. In the meantime the Bishop and Dean of Winchester met His Grace the Archbishop of Canterbury, who was conducted to his seat on the upper dais. The Bishops of Southwark, Birmingham, Bath and Wells, Wakefield, Lichfield, Worcester, Bristol, St. Asaph, Salisbury, Rochester, Chichester, Southampton, Guildford, Willesden, and the Dean of Westminster, formerly Bishop of Winchester, the Chaplain-General, Bishop Taylor-Smith, and many others, had already taken their places.

Once again a procession was formed, and H.R.H. Princess Christian of Schleswig-Holstein and H.R.H. Princess Henry of Battenburg were escorted to their places by the Dean and Vice-Dean.

Their Majesties the King and Queen having arrived at the Great West Door, were received by the Bishop of the Diocese, the Dean and Canons Residentiary, and conducted to the seats prepared for them on a special dais.

The Archbishop preached from the text in Ps. xc. ver. 17 : " Prosper Thou the work of our hands upon us, O prosper Thou our handiwork."

On Wednesday, July 17, the great Thanksgiving Service for the Diocese was attended by the Mayor and Corporation of the City, the Mayors of Southampton, Portsmouth, Bournemouth, and other towns, and the clergy from all parts of the diocese.

On Friday a further service was held for the public schools at which the preacher was a former head-master of Winchester School, Dr. Burge, then Bishop of Southwark, now Bishop of Oxford.

On Sunday, July 21, the Festival came to a close, with a very impressive sermon by the Canon-in-Residence, Canon Vaughan.

Thus ended a great event in the history of Winchester and of its Cathedral. Where all had worked so well and cordially together, it would be an invidious task to name those who specially deserved the thanks of the community. But two names stand out pre-eminently—those of Dr. Furneaux, the Dean, and Canon Braithwaite, who did so much for the care of the workmen and staff engaged in the repairs, and organised the services on Friday mornings in which the workmen of all denominations took part.

It is worthy of record, and is a special cause for gratitude, that the whole work was carried through without fatal or serious accident to any of those engaged in it, whether working high up on the scaffolds or under the dark and muddy water in the foundations.

SOME OF THE KINGS AND QUEENS OF ENGLAND ASSOCIATED WITH THE HISTORY OF WINCHESTER CATHEDRAL

A.D.

611. King Kinegils made preparations for the founding of the Saxon Cathedral, but it was built by his son Kenwalc in 639; rebuilt in 980 by St. Ethelwold; again rebuilt in 1079 by Bishop Walkelin, a relative of King William I.

That Kenwale's Church was built on the site of the early Roman Church, hallowed by Bishop Birinus [A.D. 634], is confirmed by the ancient Baptistery Well in the central crypt.

714. King Kenwalc (son of Kinegils). His remains are placed with those of King Egbert in the mortuary chests on the side of the Presbytery.

The relics of Kings, Queens, and Bishops were "chested" by Bishop de Blois about the year 1134, and two of the six exquisite chests placed on the side screens of the Presbytery by Bishop Fox, in 1554, contain the original leaden caskets made by Bishop de Blois.

827. KING EGBERT was crowned in the Cathedral as "King of all Britain."

857. KING ETHELWULF'S (father of King Alfred) remains are in the mortuary chests.

901. KING ALFRED, who lived at Wolvesey Castle, restored the Cathedral, and was buried with his QUEEN ALSWITHA at Hyde Abbey.

The Saxon Chronicle, partly written by King Alfred, was completed by the Monks of St. Swithun's Priory.

924. KING EDWARD (eldest son of King Alfred), "father and lord of all England," is buried under the south parclose.

940. KING ATHELSTAN, who increased the power of the Saxon monarchy, made Winchester his Capital and worshipped here, bestowing much treasure.

940. KING EDMUND, the son of King Athelstan, who swayed the sceptre while his father was living and maintained the supremacy over Scotland, lies in the mortuary chests.

946. KING EDRED, who fought victoriously in a time of great national strife, reigned nine years and a half, died at Froome on St. Clement's Day 955, and was buried in the Cathedral by Archbishop Dunstan.

975. KING EDGAR the Peaceful resided in this city, and reigned seventeen years. He instituted Bishop Ethelwold in the See of Winchester, and was buried at Glastonbury.

980. King Ethelred was present at Dedication of St. Ethelwold's Cathedral on October 20, 980, by St. Dunstan, Bishop Ethelwold, seven other bishops, and nearly every duke, abbot, and noble of England.

1002. King Ethelred was here married to Emma Elgiva, "the Fair Maid of Normandy." The King gave her the city of Winchester for her dowry.

1035. King Canute gave many gifts to this Church, and Emma, his Queen, gave to the Cathedral "*God-be-got*" house with its right of sanctuary. Their bones lie in the chests on the Presbytery.

1041. King Harthacnut is buried under the north parclose.

1043. King Edward the Confessor was crowned in the Cathedral by the two Archbishops as King of England.

Winchester City was a dowry of Queen Edith, wife of Edward the Confessor.

1070. King William I was recrowned in Winchester Cathedral by three Papal Legates. He was wont to keep the Festival of Easter in the Cathedral.

1079. The Foundation Stone of the Norman Cathedral was laid by Bishop Walkelin in 1079, and fourteen years later, on St. Swithun's Day 1093, the monks, with "the greatest exultation and glory," brought St. Swithun's shrine westward into the new Church.

1094. King William II granted to the Prior of St. Swithun's a charter for holding St. Giles' Fair. He was buried under the Tower, but some of his bones are "chested." His brother Richard is buried under the S. screen of Presbytery.

1101. KING HENRY I was again crowned, and married to QUEEN MATILDA in the Cathedral. He made his nephew, Henry de Blois, Bishop of Winchester.

1135. KING STEPHEN attended the Cathedral.

1141. The EMPRESS MATILDA was brought in a splendid procession to the Cathedral by Bishop Henry de Blois and other Bishops and Abbots, the Nuns of St. Mary's Abbey walking unveiled before her.

Bishop de Blois founded St. Cross Hospital and built Wolvesey Castle in this reign.

1172. KING HENRY II, with QUEEN MARGARET OF FRANCE, was crowned here, and in 1175 here received the Patriarch of Jerusalem, who came to present him with the keys of the Holy Sepulchre.

1194. KING RICHARD I was recrowned in Winchester Cathedral with unusual magnificence on Low Sunday.

In this reign the Eastern Aisles were reconstructed by Bishop Godfrey de Lucy.

1213. KING JOHN met the Archbishop and Bishops at the West Door of the Cathedral on the day that the Papal Interdict was removed from the kingdom. ISABELLA, his Queen, gave birth to a son (Henry of Winchester) in the Castle.

1259. KING HENRY III held a Council in the Chapter Room. He lived much in Winchester.

1276. KING EDWARD I and QUEEN ELEANOR attended the Cathedral in state, and the King held a Parliament at the Castle which lasted three weeks.

1349. KING EDWARD III by a new charter granted to the Prior of St. Swithun's the right to keep open the Fair on St. Giles' Hill for three weeks.

The casing of the Norman Nave in Perpendicular Gothic was commenced in this reign.

1382. KING RICHARD II and his QUEEN attended Service here during repairs to the Great Hall at Winchester Castle. The Foundation Charter to Winchester College was granted in this year.

1403. KING HENRY IV was married in the Cathedral to JOAN OF NAVARRE, DOWAGER DUCHESS OF BRITTANY.

1404. KING HENRY V worshipped in the Cathedral when a student at the College.

1448. KING HENRY VI was often at Winchester, and attended the Enthronement of Bishop Wayneflete.

The Cathedral Screen, the City Cross, and Cardinal Beaufort's Quadrangle at St. Cross were built during this reign.

1469. KING EDWARD IV came frequently to the Cathedral and to the College.

1486. KING HENRY VII was a Benefactor to this Church. His Queen built the east end of the Lady Chapel; and his son, PRINCE ARTHUR, who was born in St. Swithun's Priory, was christened here, his mother, ELIZABETH OF YORK, carrying him to the Altar.

1522. KING HENRY VIII and the EMPEROR CHARLES V came to this Cathedral and viewed St. Swithun's costly shrine. The King, who stayed a week in Winchester, rededicated this Cathedral to the Holy Trinity.

1553. KING EDWARD VI, when at the Cathedral, ordered a Library to be founded.

1554. KING PHILIP OF SPAIN was married in this Church to QUEEN MARY on July 25. The King was lodged at the Deanery and the Queen at

Wolvesey Castle, Bishop Gardiner providing the wedding dinner in the Great Hall.

1570. Queen Elizabeth came in state from the Castle to the Cathedral, and also visited the College.

1603. King James I attended the Cathedral Services while staying at the Castle.

1635. King Charles I, while staying in Winchester, signed the Book containing the Cathedral Statutes.

The Vaulting under the Tower was inserted by King Charles I.

1682. King Charles II stayed at the Deanery, and laid the Foundation Stone of the King's House on October 23, 1682.

The Service Books now on the Cathedral Altar were presented by King Charles II, and a Gallery at the Deanery was built as a Reception Room for the King.

1685. King James II attended Service at the Cathedral on September 14, and afterwards interviewed Bishop Mews on the question of the baptism of slaves.

1705. Queen Anne and Prince George of Denmark attended the Cathedral Service.

1778. King George III and Queen Charlotte several times attended Service at the Cathedral.

1832. Queen Victoria, accompanied by her mother, the Duchess of Kent, stayed at the George Hotel, and visited the Cathedral and the Hospital of St. Cross.

1849. Prince Albert, after presenting new colours to the 23rd Regiment, came to the Cathedral and paid a visit to the College.

1884. King Edward VII and Queen Alexandra, when Prince and Princess of Wales, visited the

Cathedral. King Edward also came to Winchester in 1893 and 1899.

1908. Queen Mary, when Princess of Wales, visited the Cathedral.

1910. King George V, when Prince of Wales, unveiled the K.R.R. Memorial Window in the Cathedral.

1912. King George V and Queen Mary attended on July 15 the Thanksgiving Service for the completion of the work for the preservation of the Cathedral.

CHAPTER XIII

OTHER CATHEDRALS: PETERBOROUGH, CANTERBURY, LINCOLN, EXETER

In this and the following chapter I propose to describe the means which were adopted in saving several of these ancient monuments.

The British Islands are so rich in cathedrals, abbeys, churches, castles, and other ancient buildings, and so many of these are suffering from the ravages of time, that it is our bounden duty to do our best to preserve them for the use and delight of many generations to come, even as they have been handed down to us by our ancestors.

When we look at these noble buildings and consider the enormous expenditure of money and of thought, of skill and of taste, bestowed upon them, and remember that they are heirlooms, forming a priceless history of art and architecture, the capital cost of which we have not to pay, the least we can do is to keep them in repair. In effecting this, we should aim at adopting some system that will not attract attention. The characteristics and features, the old stones with their cracks and deformations, with their weather-worn arrises and surfaces, with the very moss, should, if possible, be preserved. Where the actual stone has perished it must, of course, be replaced by new; but walls that are simply cracked, or are within certain limits out of upright, should be secured without removing or renovating the constituent parts.

The first work that I ever carried out in connection with cathedrals was, however, not quite in this category. In 1881, between Westminster Abbey and the public road on the north side, the disused burial-ground attached to St. Margaret's Church was a dreary-looking place with its pavement of old gravestones or slabs of various sizes and shapes, some broken, the rest in any position except standing upright. A friend of mine, who did legal work for the Houses of Parliament, proposed laying down a sward of grass and giving the Abbey the bright green Close appropriate to such buildings. I, as a friend, prepared a plan for him which was exhibited in the Tea Room of the House of Commons. The broad pathways which now give access both to the Abbey and St. Margaret's Church, were shown on the plan.

The proposal having received the approval of the authorities, the necessary funds were raised by subscription, and as complete a list as possible was made of the graves. The whole area was then covered with mould six inches in thickness and grass seed was sown. In twelve months time the fine green sward which is now to be seen, had replaced the old dreary waste. It is not too much to say that this setting of well-kept grass has greatly beautified the Abbey precincts.

Peterborough Cathedral

Peterborough was the first cathedral upon which I reported officially, and I visited the fabric on

January 26, 1897. I had been staying with my dear friend Dean Argles at his very interesting Rectory of Barnack, and was requested by the Bishop of Leicester, the late Bishop Thicknesse, to examine the fabric. A suggestion had been made for altering the method of preservation which was then being carried out by the late Mr. Pearson, the able architect to the Dean and Chapter.

There were dangerous fissures in the West Front, some of them as much as 9 in. in width. Prepared as I was to see the disintegrated mortar running out like sand from an hour-glass, I had not expected the gaping cracks which I actually found. My only surprise was that some accident had not occurred to the structure.

The preservation of the old stones, and above all of the old colour, which it had taken more than 600 years to produce, was one of the first objects. Very rightly this had received the earnest and careful attention of the architect and his experienced clerk of works Mr. Irvine, as well as of Messrs. Thompson & Son, the contractors. They had adopted the only safe method, namely, to remove the gable of the west front, the stones of which were most carefully handled, numbered and kept close at hand for replacement. I strongly advised that no change should be made, and the work was completed as it had been begun.

Canterbury Cathedral

In 1909 I was asked by the architect of the Ecclesiastical Commissioners to explain to him

LINCOLN CATHEDRAL.

This fine photograph was taken from the recently constructed Water Tower, and enables the comparative heights of the Towers to be better realised. Height of Central Tower, 275 ft.

the working of the grouting machine. I did so with much pleasure, and lent him the machine itself for use on Glastonbury Abbey. The results were so satisfactory that I again lent the machine, which was sent on to Canterbury Cathedral in order to strengthen the piers of the Bell Harry Tower. The only condition for which I stipulated was that I should be allowed to see the work in progress, to make sure that on such an important fabric the machine was being correctly applied. Unfortunately this condition was overlooked, but from what I saw after the work had been finished, and from what the workmen said, I gathered that the cementing was not done from the base of the piers but from the top. If this were the case, the tower did not receive the benefit of being treated with cement under pressure, according to the process described in Chapter XII.

Lincoln Cathedral

Lincoln Cathedral is, perhaps, the most magnificent of all the cathedrals in the British Islands. Ruskin thought that "it was equivalent to any two others rolled into one."

Lincoln,[1] or Lindum signifying "the fort by the pool," was originally a Roman colony—like Gloucester, Colchester, and York. The Romans were the first to undertake the draining and embanking of the fens and marshes. Their engineering skill turned the latter into rich productive farm land. Towards the end of the third century

[1] The first part of this section is based on notes very kindly supplied to me by Dr. Fry, the present Dean of Lincoln.

came the Saxon sea-rovers, followed by the Pictish tribes from the north, who broke through the Wall of Hadrian and in concert with the sea-rovers reached the very gates of London.

When the Roman legions were finally withdrawn in A.D. 410 their relentless foe burnt the villas in Lincoln and elsewhere, destroyed industry, broke down the banks of the drains, and sent back the cultivated land into prairie. The drained fens again became flooded ; and the civilisation of Lincoln, as of Roman England generally, suffered extinction.

After the Saxons came the Danes, first to ravage then to settle, and twelve Danish Lawmen ruled in Lincoln. Christianity had been first planted by Paulinus, and the first Christian Bishop of Lindsey had his bishop's stool at Sidnacester (generally held to be Stow).

Last of the invaders came the Normans. William I, after his march to York to put down the first northern rebellion, passed along Ermine Street, through Lincoln ; but he left the Lawmen undisturbed and began the construction of the Keep of a new castle on the Hill.

Amongst the ships offered to William I for his invasion of Britain was one with twenty knights supplied and paid for by Remigius, Monk Almoner of Fécamp in Normandy. He had his reward at Christmas, A.D. 1067. He was appointed to the See of Dorchester, vacant by the death of the English Wilfrid. He was transferred from Dorchester to Lincoln, secured by its new castle, and received from the King a charter for the site of the cathedral, a copy of which is preserved in the Cathedral Library. A Saxon church had already stood on this site, and traces of it still remain underground.

Remigius built a cruciform church 300 ft. in length with a choir of three bays and a semi-circular apex with timber roof, but he died before its consecration in A.D. 1092. His second successor Alexander the Magnificent added to the work, and it is said that in A.D. 1141, when the timber roof was burnt, he replaced it with a ceiling of stone. The interesting arcade upon the towers and the lower portions of the towers themselves are his.

In A.D. 1173 Henry II sent abroad for a successor to the Bishopric and appointed the famous Hugh of Avalon of the Grande Chartreuse. Hugh was a saint; humbly unselfish, devoted to the cause of the poor, to his church, to God and to Righteousness; yet, for all his humility, this was the man who dared to excommunicate the King's chief forester, to refuse a benefice to a great courtier, to oppose a grant for foreign war to Richard I, and to bring John himself to submission.

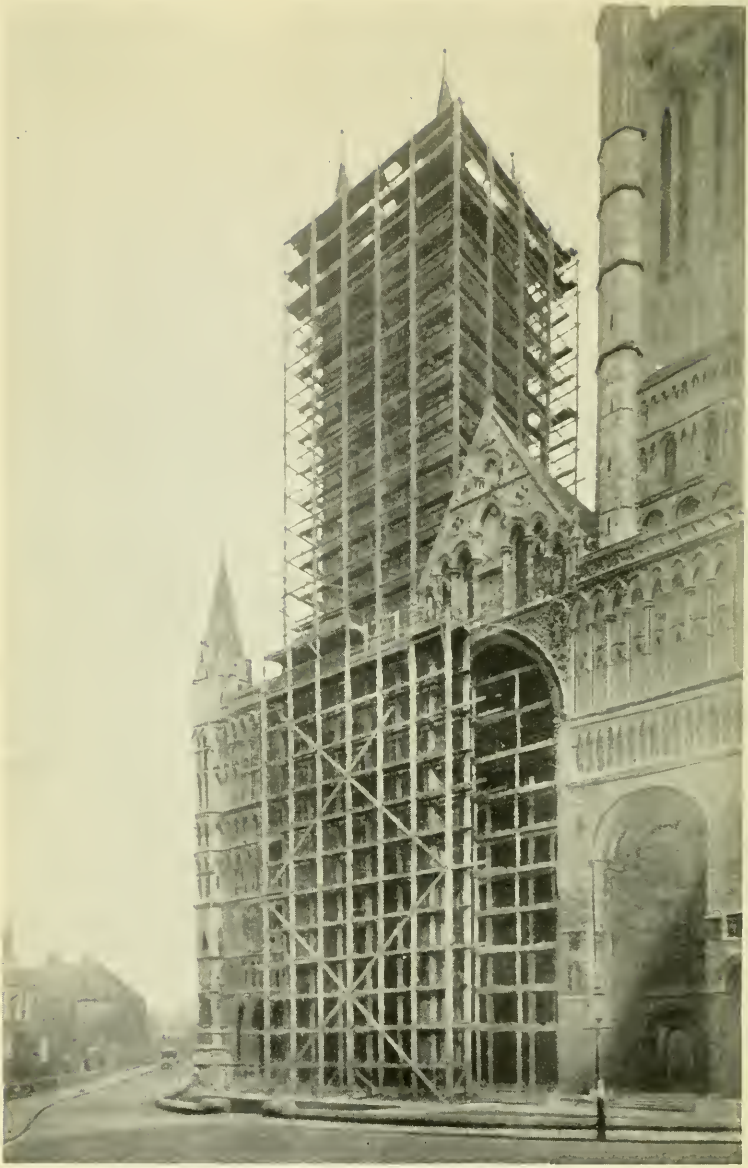
He found his church practically a ruin—the nave, transepts, and choir had all fallen, and only the two western towers remained. When we began in 1922 to investigate the cause of the grave injury which had accrued to the towers, we had no knowledge of what had caused this great destruction, and it was not until the account written by the historian Roger de Hoveden in A.D. 1185 came to light, that we were told how "a great earthquake, the greatest ever known in England, had split Remigius' church from top to bottom."

Hugh decided to build again, preserving the two western towers. The parts of the Cathedral erected by St. Hugh now remaining are the choir, the choir aisles, the smaller east transepts, and two bays on each side of the greater western transepts. What Diocletian did for the round arch at Spalato, Hugh did at Lincoln for the pointed arch. It had already been used in Saracen mosques, and even in Pisa, but at Lincoln for the first time it now became the dominant feature.

St. Hugh died in A.D. 1200, but in A.D. 1205 his work was continued. The nave was completed, and it was decided to retain the western towers. The central roof in the east north bay was raised to meet the newer and loftier Early English roof.

In A.D. 1255, the Dean and Chapter resolved to build a shrine fitter for their saint. They pulled down Hugh's east end, and from the East Transept built the famous Angel Choir in the Geometrical or Decorated style. They transferred Hugh's body to the back of the High Altar, and all England came to assist at the ceremony. It was attended by Edward I, the greatest of our Kings, and his noble wife Eleanor of Castile, Archbishops, Bishops, Barons, and the people whom Hugh had loved and served.

The Angel Choir was finished about 1282; but before this date Grosseteste, the second greatest man amongst the Lincoln bishops, had seen the



LINCOLN CATHEDRAL. WEST FRONT.

The great scaffold for repairing the North-West Tower, 215 ft. in height. When completed the scaffold will be moved to South-West Tower.

church almost complete. Edward I held two Parliaments in the Chapter House. The Cloisters followed soon after. But disaster occurred in the fall of the Central Tower erected by St. Hugh. It was re-erected on strengthened piers in A.D 1307 by Grosseteste, who carried it to its present height. The two western towers were similarly raised somewhat later (A.D. 1400).

Such is, in outline, the history of the fabric of Lincoln Cathedral, founded more than eight centuries ago.

We now come to the repairs carried out during the last two or three years. It is a remarkable coincidence that just as Grosseteste (A.D. 1307) contributed so much to the dignity and nobility of the Cathedral, so has the grouting machine, invented by Greathead (also Grosseteste), contributed to its safety and solidity.

The measurements of the Cathedral are as follows :

Its external length is 514 ft. 7 in.

Its internal length is 480 ft.,

of which the Nave occupies 211 ft. 6 in. The great Transepts are 223 ft. long internal, 248 ft. 8 in. long external. The height of the western towers is 212 ft., whilst that of the central tower is 271 ft. The diameter of the beautiful Chapter House is 60 ft.

About the end of 1921 I was requested by the Dean to report on the condition of the fabric, and to collaborate with Sir Charles Nicholson, Bart., with a view to advising what steps should be taken to preserve it from accident.

In this work we received most valuable assistance from the able Clerk of the Works, Mr. Robt. S. Godfrey, whose mechanical ability is of the highest order. We could not recommend the examination of the foundations, until the very serious cracks and disintegration in the western towers were to a considerable extent corrected; otherwise there might have been a disaster.

With the experience of the grouting machine behind us, I strongly advised the authorities to employ it. My advice was followed. The walls of the North-West Tower were soundly grouted up. Large cavities and cracks of 12 to 14 in. in width, which could not have been dealt with in any other way, were filled solid. In addition, fine ties of Delta metal (an alloy of copper and other metal which is incorrodible and has the strength of steel) were inserted into all the holes drilled in the ancient masonry, after which they were grouted up.

High-speed jack-hammer drills were used, giving 500 blows per minute, and boring to a length of 16 ft. in five to eight minutes. With the aid of a high-pressure water spray (to moisten the masonry and to lay all dust) very rapid progress was made at a fraction of the cost of all previous methods.

It is no exaggeration to say that such speed, efficiency, and economy have never been approached in any other cathedral work. By the methods described, vibration was reduced to a minimum; and we avoided the nuisance of covering the whole cathedral with dust.

We decided not to attempt to investigate the

LINCOLN CATHEDRAL. NORTH-WEST TOWER.

Circular Norman Staircase discovered in the thickness of the Norman wall, extending from nave floor to a height of 70 ft.

LINCOLN CATHEDRAL. NORTH-WEST TOWER.

Drilling 14-ft. holes into the masonry by "Jack-hammer" drills, in readiness for the insertion of Delta metal rods and the process of "grouting."

foundations until the North-West Tower should have been secured to a considerable height. When this had been done, any movement of the upper portion would be arrested. Personally I was convinced that the foundations were not in fault, as the plinths were level, and in fact it has now been ascertained that the cathedral is founded on rock.

The first matter of interest which we encountered was the "Dungeon" which in early and mediæval days was used for the confinement of prisoners who were shortly to be executed. This chamber, which is on a level with the floor of the Cathedral, is 20 ft. in length, 6 ft. in width, and has a height of 20 ft. It had no door nor window, not even a ventilator. The unhappy prisoner was lowered by a rope through a trapdoor in the stone arch above, and taken out in the same manner to his death.

It reminds one of the cell at the Mamertine Prison in Rome, in which St. Paul is said to have been confined and from which he wrote his last chapter of peace and joy in the Epistle to Timothy.

As the work of repair travelled upwards, the condition of the Norman masonry steadily grew worse, until it reached such a state of disintegration that we almost abandoned hope. But with patience, and the greatest care on the part of all, aided by the invaluable grouting machine, we succeeded in consolidating even the worst of the masonry. How bad that "worst" was, will be evident when I say that much consisted of rough rubble *in movement*, together with great quantities of rubbish and dust.

About 70 ft. from the floor we found what evidently was a doorway built up with masonry. Of course this could not be passed by without investigation. The walling of masonry, on being removed, disclosed a circular stone staircase communicating with the floor of the nave, with the original stone newel. No record of the existence of this staircase existed. It was filled with debris from the earthquake, for its entire height.

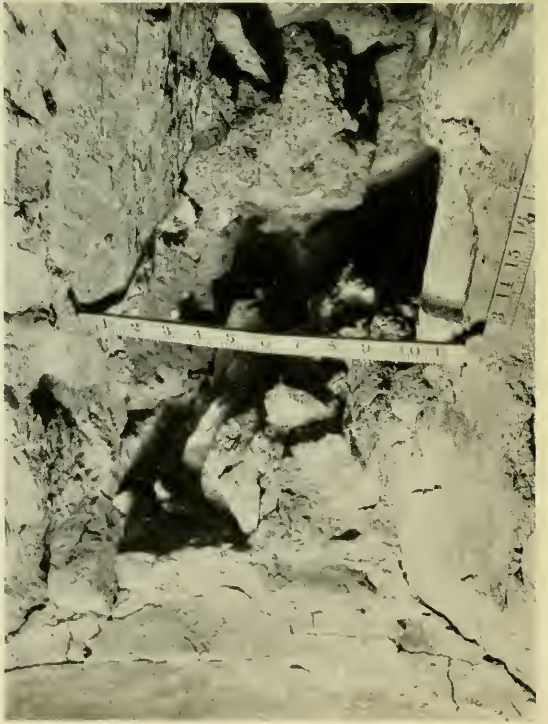
As the work proceeded, the great fractures, 12 inches or more in width, were followed and corrected ; but an even more dangerous weakness was discovered. The fine West Front (which is 200 ft. in length and 100 ft. in height, and was built by St. Hugh in A.D. 1187 as a buttress to support the towers) was found to have become detached from the Norman masonry, and was threatening to fall like the cover of a book, on to the turf of the Close.

All this, however, so far as the North-West Tower is concerned, has now been made secure ; and so soon as the scaffold can be removed from the North-West to the South-West Tower, the remaining half of the West Front will be consolidated.

The scaffolding itself is a remarkable piece of work. It is 212 ft. in height, 35 ft. wide, and 36 ft. long. It is constructed of three 9-in. planks for each upright, and is "standardised" so that any planks or bolts taken up promiscuously are sure to fit. It is the finest example of such a scaffolding in existence, and is a monument to

LINCOLN CATHEDRAL. NORTH-WEST TOWER.

Crack 150 ft. from floor, discovered by the removal of plaster, filled in with wooden wedges for some unknown reason.



LINCOLN CATHEDRAL. NORTH-WEST TOWER.

One of the great cracks in the Norman work caused by the earthquake A.D. 1185. A scale is placed across the fissure to enable readers to judge for themselves.

the skill of those who designed and constructed it. In no place is it more than $\frac{1}{32}$ of an inch out of truth.

By the help of this scaffold the external masonry of the tower has been examined. It was found to be so weathered and broken that almost the whole 9 ft. of the top of it must be refaced. The stone is now being dressed for this purpose.

Another unpleasant discovery made during the work on the North-West Tower was, that in the very rotten timber floors of that structure much damage had been done by the "death-tick" beetle or *Xestobium tesselatum*—the same insect which all but destroyed the fine timber roof of Westminster Hall. At Lincoln the floors have been reconstructed in ferro-concrete, which no beetle yet discovered can touch.

The repair of the great central tower has been begun, thanks to the kindness of our Canadian and American friends. The first step was to examine the masonry of the abutting transept walls which act as buttresses to the tower. A scaffold has been erected inside the Cathedral up to the vaulting of the transept, some 70 ft. in height. We have found the masonry hollow and defective; it is, in fact, the commonest rough rubble, destitute of any mortar. This, however, has been quickly put right by blowing in cement, but scarcely a week passes without further defects being discovered. Nevertheless, it is confidently hoped that by June 1926 the whole of the repairs will be completed, and the total expense defrayed. In a structure so ancient and so big, we cannot hope that no further repairs will be required. These are inevitable, but, once the fabric has been rendered monolithic, the Cathedral staff and funds will doubtless be sufficient to meet all the requirements of the future.

Since the above was written, very serious cracks have been discovered in the South Transept. The length of this is 90 ft., but the aggregate length of the cracks in the vaulting is 314 ft.—the width varying from 2 to 6 in. : these have been discovered by the removal of the accumulation of plaster, dust, and disintegrated masonry of centuries which could not be reached until we had erected the necessary scaffold.

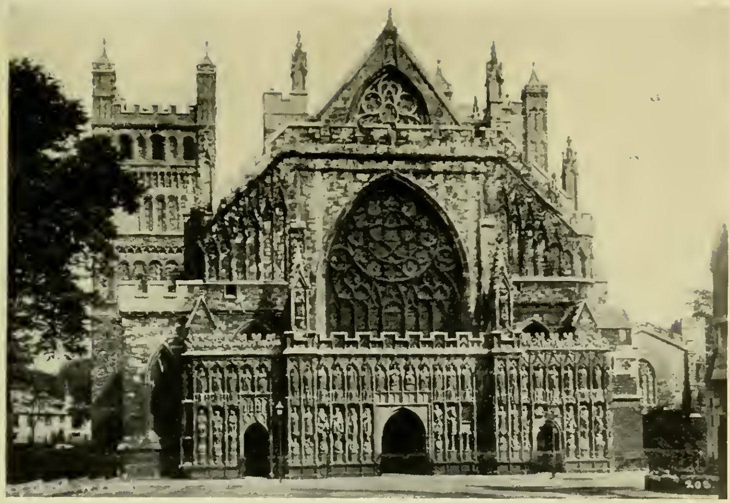
Exeter Cathedral

The Cathedral of Exeter is one of the smaller but most beautiful minsters of England, and stands on high ground above the valley of the River Exe.

It is in very good condition excepting for the usual and apparently inevitable flaking off in places of the external face of the masonry. This work of repair is now completed.

The Cathedral stands upon the site of a Saxon, and afterwards of a Norman church ; but the present fabric dates from about A.D. 1100 when the two Norman towers were constructed, one on the north, the other on the south side of the nave, and the building was gradually transformed into the cathedral as we have it to-day.

The nave is 350 ft. in length with a space from



EXETER CATHEDRAL. WEST FRONT.

EXETER CATHEDRAL.

Portion of the timber roof for the protection of the fine groined Masonry Arching. This timber-work was constructed about A.D. 1300, but from some unknown cause is seriously out of upright, as indicated by the "plumb-bob" and "scale."

wall to wall of 34 ft. It is roofed in by beautiful groining which extends for the whole length of the building. But about A.D. 1300 it was surmounted by a timber roof, to protect the fine masonry from rain and snow. This timber roof was constructed of solid English oak, but some accident or slip must have occurred, probably during its erection ; for every principal (of which there are forty) is out of upright, and so, too, are all the intermediate timbers.

Many additional struts have been added to the structure by succeeding generations. The photographs will illustrate the very abnormal condition of the roof better than any description. A scale and " plumb-bob " are shown, by which the reader can check off for himself the divergence from the perpendicular.

At the worst, this divergence is as great as 6 ft. 4 in., and the principals are tilted to such an extent that on one side they are standing on their edges, and on the other side one can easily insert the front part of one's foot.

In addition, however, to this very serious movement, which is still going on, great ravages have been made by the " death-tick " beetle—*Xestobium tesselatum*—as at Lincoln Cathedral, Westminster Hall, St. George's Chapel, Windsor, and many other buildings.

So serious is the damage that there are actual gaps, two or three feet in length, in some of the main timbers. The latter are all being removed and sound oak substituted in their place.

Some sixty years ago Sir Gilbert Scott was consulted, but declined to undertake the responsibility of restoring the roof to a vertical position. He introduced some iron tie rods and additional timber struts which have done useful work. Now, however, something more is required. But, to rebuild the roof, it would have to be entirely removed. This would expose the beautiful groined masonry beneath to the rain and snow, and inevitably lead to its being stained. However carefully it might be covered with tarpaulins, these would be liable to be ripped, and torn by the gales.

In addition to this objection, the cost would be very great. Moreover, there is the possibility of some of the timber falling on to and injuring the groined work.

After carefully weighing all the advantages and disadvantages, the Diocesan Architect, Mr. Harbottle, and I decided not to incur the risk of attempting to place the timbers upright, but to make the work as safe as possible in its present position.

Great care had to be taken not to increase the weight in any appreciable degree. Accordingly we removed all debris of masonry and plaster, and all unnecessary timbers. A light steel bracing is now being fixed.

When this is complete, it will always be easily accessible for painting and examination, and it will impart to the roof an appearance of tidiness and simplicity which has long been absent from it.

Half the total length of roof has been repaired, and it is expected that the whole work will be completed by the autumn of the present year

(1924). To Mr. E. H. Harbottle many thanks are due for his great care of the Cathedral.

In that interesting book, *The Story of the Renaissance*, by Sidney Dark, a very appropriate paragraph is given, which may, with satisfaction, be here quoted to close this chapter :

" It may indeed be safely said that nothing that the Renaissance left behind it, not even the frescoes of Michael Angelo, the Virgins of Raphael, or the plays of Shakespeare, are to be compared with the great Cathedrals that remain for us, the monuments of the piety and the comradeship of the Middle Ages."

In conclusion, we cannot but realise what a privilege it is for men of our time to be engaged in saving these mighty fanes which stand as monuments of a living faith in Almighty God.

I cannot allow this chapter to close without reference to the splendid work which our good friend the Dean of Lincoln, Dr. Fry, carried out for saving his great Cathedral. Morning, noon, and night has he worked beyond his strength, raising the necessary funds, and twice has he visited Canada and America at great personal inconvenience. Those of us under his direction and the whole staff have endeavoured to share his burden, and reduce the cost by the adoption of machinery for drilling, grouting, and stone-dressing by compressed air.

The result is attained in a remarkable degree by work being done in one hour which twenty years ago occupied a week, and the cost in some items has been reduced from one pound to one shilling.

CHAPTER XIV

CHURCHES AND BRIDGES: CORHAMPTON, BLETSOE, LYME REGIS, ST. MARY, BISHOPHILL JUNIOR, YORK, ASHBOURNE, BOW CHURCH, FORD END, PORTINSCALE, OXENHULME

CORHAMPTON

THE ancient Church of Corhamptom, near Bishop's Waltham, in Hampshire, is another satisfactory instance of the application of the grouting machine. This Saxon Church, 1,300 years old, was in a sadly dilapidated condition. In the west gable there were three large cracks, one from the ridge to the ground wide enough for a man's arm to enter; another, nearer the side wall, wide enough for the insertion of his head, whilst at the north-west angle the Saxon work threatened to fall bodily off. The mortar of the walls had perished through age, and the ivy had penetrated into the interior of the church in every direction, and was attending divine service. It would have been unsafe to attempt any examination of the foundations for fear of bringing down the whole fabric; consequently the grouting machine was applied all over the building. The "grout" escaped at every point, and the masons both inside and outside had to stop it promptly by dabbing red clay on to the openings from which it was running. By the time the walls had taken all the grout that could be forced in, the church was practically a red building both inside and outside, from the extensive use of this red clay, but this was all removed on completion.

The cracks were in places so wide that they had to be specially treated before commencing to grout them, and the clay was so arranged as to extend into the crack about an inch on both faces. After the operation had been completed and the cement had set hard, the clay was removed and the interior was found to be filled with adamant ; but as it did not come within an inch of the face of the wall, sufficient depth was left for fixing the flint work outside, and tiling inside. The result is that no trace of the crack is visible, and after this treatment of the walls they are stronger and better than they have ever been. Steps were then taken to examine and, where necessary, to underpin the walls, and we have the satisfaction of knowing that these efforts have saved the church. The Vicar, the Rev. H. Churton, writing on the subject on October 18, 1906, said :

" The grouting was most effective, and I think the walls are now quite safe, and all without moving one of the Saxon ' long and short ' stones."

BLETSOE CHURCH NEAR BEDFORD

In December 1907 I was asked by the Rev. R. H. Moss, vicar of Bletsoe Church near Bedford, a former college friend at Cambridge of my son the late Charles Beresford Fox, to come and examine this old church, which I gladly did simply as an acquaintance.

I met there the late Lord St. John of Bletsoe, the Lord of the Manor, and churchwarden, and with him made a careful examination. The tower was cracked from top to bottom in several places ; the Chancel wall had three ominous cracks in it ; the south Porch had moved bodily five inches away from the main building, leaving a wide crack all the way round ; and the Vestry on the north side had followed the example of the Porch.

Lord St. John informed me that the cost of repairing the church had been estimated at £1,420 ; but that the parish was a poor one, and they had only succeeded in raising £70. This sum had been banked, he said, and they awaited eventualities.

A local builder had been consulted, and suggested that the Chancel wall should be underpinned, a proceeding which in all cases should follow, and not precede, the repairs to the cracks. I found three large excavations had already been made under the Chancel wall, and without any timbering : and as it was a very wet day, the men had gone home. Meanwhile the water was running into the holes and washing down the sides ; and if this had been allowed to continue all night, the wall would probably have fallen in. It was essential to fill up the excavations at once, without an hovr's delay ; and this was done by calling in the assistance of two or three agricultural labourers.

I told Lord St. John that if he would place the £70 in my hand, I could save the church, and I sent him a very capable Scottish mason, William Glen, with a grouting machine, to do what was needed. In the course of a few weeks he had completed all the work, and with such care and skill that it was impossible to see where the repairs had been effected.

Underpinning was avoided altogether, and although sixteen years have since elapsed, there has been no sign of any further trouble.

This instance shows very clearly the advisability of making a wall monolithic. Treated by the grouting machine the wall becomes a strong girder, and underpinning is often rendered unnecessary.

Lyme Regis Church

During the holiday season in 1910 we selected Lyme Regis for a much-needed rest, and saw for ourselves the danger threatening its ancient and historic Parish Church of St. Michael's—a fine example of fifteenth-century Perpendicular Gothic—from the continual encroachment of the sea, and the wearing away of the cliffs.

Within the memory of many of the townsfolk at that date, there had been two fields between the churchyard and the edge of the cliff, but they had in 1910 disappeared, and a portion of the churchyard itself had wasted away.

I called on the then Vicar, the Rev. William Jacob, and pointed out to him the risk to which the church was exposed of being undermined and washed away—the top of the slips being already within 20 or 30 ft. of the Chancel wall—

and not only the church, but the main street was threatened with its houses and with the picturesque and ribbed arches, dating back probably to the twelfth century, carrying the road from Lyme to Bridport and Weymouth, over the "Lym" or River Buddle. Only one arch is visible, which dates from the fourteenth century, the others being under adjacent houses.

A local committee was quickly formed including

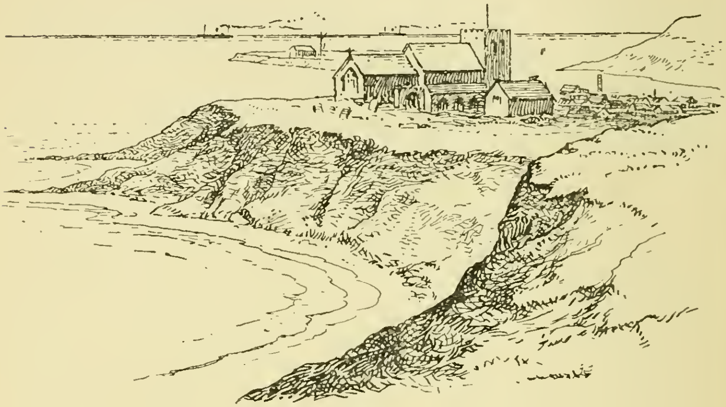


Fig. 16.

the Vicar, the Mayor and Alderman of this ancient borough, and many residents—and funds were raised for the essential safeguards from all parts of the Diocese.

Various forces were at work tending to the ruin of the Church. First, the disintegration of the shale, by the spray and fret of the sea, had exposed and undermined the beds of limestone in the cliff, which were continually falling off and carrying the cliff farther and farther inland; secondly, the breakers were lifting these limestone beds, where they cropped out over the beach; and, thirdly, the rain sinking into the subsoil under the churchyard had caused very serious slips.

A ferro-concrete wall was built on the beach, on a firm layer of limestone, thus protecting the lower part of the cliff from the action of the sea (see Fig. 17). The layer of limestone (*a*) projected beyond the shale (*b*) which was cut away by the spray—leaving the limestone beds pro-

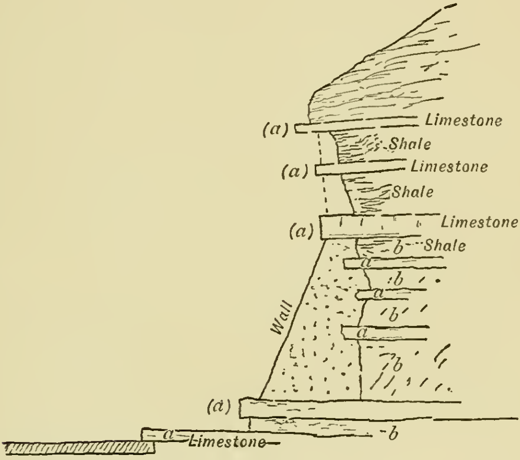


Fig. 17.

jecting, until they broke off. Now the shale has been protected by concrete—and this holds up the limestone beds.

The same treatment was accorded to the layers of stone on the beach, the work being superintended by my late son Charles Beresford Fox, Associate Member of the Institution of Civil Engineers: an experienced engineer, whose premature death was a great loss to the profession.

In October 1923 Dr. Cooper, the well-known medical man of Lyme Regis, who keeps a careful eye on the sea-wall and slopes, wrote to me saying " the sea-wall is standing splendidly."

He added that there was no movement in the grass clay slope above the cliff. The work will add many years to the age of the church and that part of the town.

This denudation of the underlying shale is practically identical with that going on under the falls of Niagara—which explains the continual receding of the falls towards Lake Michigan. A thick layer of limestone rock is resting on a cliff of shale which under the action of the spray is being eaten away until a projecting shelf some 40 ft. in thickness is left unsupported. This in course of time breaks off—and the form of the falls undergoes a change.

Until within the last forty or fifty years there was an observation tower—" Terrapin Tower "—which had been erected on some jutting rock, a good many yards behind the " lip " of the Fall. But it has now gone over the edge owing to the undermining of the limestone—and the falls have receded to this extent within a few years.

Church of St. Mary, Bishophill Junior, York

This ancient church, dating back to the Saxon period, has a fine Saxon tower and many architectural features of the same date.

The tower had some very serious cracks jeopardising its safety, and I placed the repairs in the hands of the Scottish mason, Mr. Glen ; the total cost of the work amounted to £80, and the tower will last for many centuries to come.

St. Oswald's Church, Ashbourne, Derbyshire

On November 18, 1912, I was requested to visit the old church of Ashbourne, which had been described by "George Eliot" as "the finest mere Parish Church in the kingdom, dating back to the fourteenth century—or over 500 years old."

With my old friend Colonel Jelf, one of the churchwardens, I made a careful examination of the fabric, and in a few minutes arrived at the conclusion that the south-east pier of the tower was sinking. The corner was so seriously cracked that it was threatening to fall bodily off. If this had happened, the turret carrying the bell-ringers' stairway would also have gone, and the lofty spire with it.

The tower is 75 ft. in height, and there springs from it a fine steeple 177 ft. high, making a total height of 252 ft. Serious cracks ran in all directions, both in tower and steeple, and the masonry was being crushed under the weight. In fact we found a load of masonry lying on the roof of the South Transept, which had fallen only a few days before.

The position was urgently critical, and I gave orders that the ringing of the fine bells should be stopped at once.

Colonel Jelf told me that they intended to take in hand the repairs in the following April or May; but I pointed out to him that not a day should elapse before some remedial steps were taken, or the probability was that no church would be left to repair! I advised him to telegraph at once to Messrs. Thompson of Peterborough to send on the following day their foreman and two or three men with a grouting machine, to blow cement into the worst cracks.

At the same time, I advised him to allow me to send for Sir Thomas Jackson, Bart., R.A., my collaborator at Winchester Cathedral; whose expert architectural knowledge was of great assistance.

One of the chief features of the work was the repair of the steeple, the masonry of which is 7 in. in thickness, or $\frac{1}{300}$ of the height, the same ratio which exists in the fine spire of Salisbury Cathedral.

We found that the old walls of the Nave and Aisles, and particularly of the Transepts, were very hollow and badly built—the stone had disintegrated, and it was necessary to grout up the walls throughout. These latter were bonded into the tower walls, which were strengthened by a masonry chain-bond to take the outward thrust of the steeple. Strong ties of a suitable alloy of copper were also bolted through the tower, and when this was completed, all the cracks in the steeple were filled up with cement, and new bond stones replaced the crushed masonry.

The repairs were executed with great care and skill by Messrs. Thompson.

To the delight of all the residents for miles around on July 19, 1919, Victory Day, the fine peal of bells sent their welcome message up and down the Ashbourne Valley, after an enforced silence of six whole years. Colonel Jelf unhappily did not live to see the completion of the work.

Bow Church

About the time of the opening of the Central London Railway, an alarming paragraph appeared in a certain London daily paper, renowned for its accuracy, to the effect that owing to the tunnelling operations, the spire of Bow Church in Cheapside was 13 ft. 6 in. out of upright.

The Rector and his Wardens were consequently perturbed by this statement, and requested us to examine and report on the subject. In the course of our investigation, several matters came to light which are of considerable interest, and deserve to be placed on record.

It was deemed advisable, pending the investigation as to the cause and extent of the injury, to stop the pealing of the bells—which was accordingly done, and a facetious friend commenting upon this remarked that, as we all know those children born within the sound of Bow Bells are "cockneys," the curious result was that, for the time during which the bells were silent, no "cockneys" were born.

It appears that the foundations of the tower and spire stand upon the ancient pavement, of Roman times, of Cheapside, which to-day is some 18 ft. below the present level of the street.

This continual raising of the level of London is doubtless due to the fact that the rubbish, resulting from the various fires from which the City has suffered in years gone by, and from the demolition of buildings, was not carted away, as is done today; but the surface was simply levelled down, and the new buildings erected upon it.

That there were cracks in the portion of the fabric connecting the church with the tower, is undoubtedly true, but that they were of ancient origin, is no doubt also correct. Our task was to ascertain whether the tower and spire were out of perpendicular, and if so to what extent.

At first sight, nothing seemed easier than to drop a plumb-bob and line from the top of the spire to the ground, but we soon found that there was no access to the upper part of the steeple, and that if it had to be reached, it would be necessary to erect a scaffolding—a matter of considerable expense.

We therefore decided to take the necessary measurements and angles by means of theodolite observations from both ends of Cheapside: but now a fresh difficulty presented itself.

Owing to it then being winter, the mornings and evenings were so dark, that the traffic had commenced and continued to run, before and after any such steps could be taken.

We therefore had to wait until the summer, when in the early mornings we could have the free use of Cheapside before carts had commenced to pass. But we found that, although no traffic was passing, the vibration in the instrument was so great that no accurate result could at first be ascertained. The goods traffic on the London, Chatham and Dover Railway passing over Ludgate Hill, the early trains on the Central London and District Railways, and even on the Metropolitan Railway at Farringdon Street, all recorded themselves on this delicate instrument, and we began to think we should fail to obtain any reliable result, and that London was never free from tremor.

At last, however, it was found on a bright summer's Sunday morning about 4 a.m. that the throb and vibration of London had ceased for a short period, and just at that moment we were able to obtain accurate measurements.

Instead of 13 ft. 6 in. (which of course had been misprinted instead of $13\frac{1}{2}$ in.), we found that the total divergence from a vertical line was 8 in., which was exactly accounted for by the small cracks visible in the walls of the structure.

Ford End Church

This is a modern church, only twenty years old : badly cracked, and the Chancel roof just about to collapse and to fall into the church.

I do not desire to weary my readers by an account of the same method of saving the fabric by grouting, but an amusing episode occurred which is too good to be lost.

It was noticed that, in this purely agricultural district, the raising of the necessary funds was difficult. I suggested that this was due to bad harvests, but I was assured this was not the cause, and a farmer went to the Vicar to explain the reason. He said :

" We farmers don't believe in this grouting, so we have looked out the meaning in a dictionary : the definition given is that ' to grout ' is to blow liquid cement into a wall, and turn it into a monolith. On turning to see what a monolith is, it is described as a solid block of rock or stone.

"We don't want our church to be made into a solid block of rock or stone—it would not be possible to walk along the Nave or the Chancel. The pews and pulpit would be buried in cement, and although this would make the church much firmer, we don't see the use of making it stronger if we could not use it afterwards. We should have to hold the services in the churchyard, which would be very cold and disagreeable."

Portinscale Bridge, Derwentwater

In 1911 the late Rev. Canon Rawnsley wrote to ask if this picturesque old bridge could be satisfactorily repaired, so as to obviate the necessity of its removal by the Cumberland County Council, who proposed to construct an entirely new bridge with costly approaches amounting probably to £8,000.

A strong local committee was formed for the defence of the old bridge—and after a prolonged contest, extending over a period of seven years, permission was given for the extension and repair of the structure. It was originally a pack-horse bridge dating back to A.D. 1300, and many years ago it was doubled in width.

It was completely repaired, without any alteration in its appearance, for £612, and is to-day carrying the heaviest motor-lorries and wagons.

The Royal Automobile Club rendered most valuable aid in getting the old bridge retained as being a very picturesque object in the landscape and attracting many of their members into the district.

The Old Mill Bridge near Oxenhulme

The saving of Old Mill Bridge near Oxenhulme by the grouting machine may be briefly referred to here, in order to illustrate once more the extraordinary cheapness and efficacy of this method of saving old structures. The bridge is an arch of 22 ft. span—and was originally a pack-horse bridge, about 6 ft. in width. At some period in its history it had been widened—and then the operation was repeated later on, until its width between the parapets was 22 ft.

When I saw the bridge it was very seriously cracked and some of the arch stones had fallen out badly. I sent Glen to repair it—and the total expense worked out at only £50.

The county of Westmorland are much indebted to Col. J. W. Weston, M.P., for his prompt action in the matter. Since that date, several other bridges have been saved by the application of the grouting machine, amongst which may be mentioned Bideford Bridge in Devon, the Bridges of Grange and Portinscale (so closely associated with the memory of the late Rev. H. D. Rawnsley, Vicar of Crossthwaite and Canon of Carlisle Cathedral), and the ancient bridge across the River Dee at Chester. Many structures on the main railways of the kingdom have been repaired instead of being demolished ; and I venture to think that other important bridges of Great Britain could also be preserved if judiciously treated by the grouting method.

CHAPTER XV

THE NURSES' HOME IN GREAT ORMOND STREET

It was by a happy accident that I learned of the danger threatening the Nurses' Home in Great Ormond Street, and was able to avert it. On Saturday, April 13, 1912, Mr. John Murray and his son called to see Lady Fox and myself. In the course of the conversation, he happened to mention that this Home attached to the Hospital for Sick Children in Great Ormond Street had been declared by the District Surveyor to be a dangerous structure, and was to be demolished. In consequence of this the staff had vacated the premises, the furniture had been removed, and on Monday or Tuesday the "housebreakers" were to begin their operations. This, said Mr. Murray, was a very serious blow to the hospital. Not only would there be the difficulty of housing the staff for two years, but an entirely unexpected expense of £4,000 to £5,000 would have to be met.

I offered to go, in my capacity as a friend, and inspect the house on Monday morning, and as a committee of the hospital was to meet that afternoon I undertook to report at once, in time for the meeting, whether in my opinion the structure could be saved or not.

I found that this picturesque house was built some 250 years ago, between the Jacobean and

THE NURSES' HOME FOR THE HOSPITAL FOR SICK CHILDREN IN GREAT ORMOND STREET, PRESERVED BY "GROUTING MACHINE."

Queen Anne periods ; it was enclosed by handsome iron railings, and had a fine oak staircase, panelled walls, moulded ceilings, and marble mantelpieces, and had probably been the residence of a French Ambassador. It has been stated that it was from this house, then occupied by Lord Chancellor Thurlow, that the Great Seal of office was stolen on the night of March 24, 1784.

The house was built of brick in lime, and in the basement and ground floor had framings of timber, many of which were rotten. There were no footings, and the lime in the mortar in the course of two hundred and fifty, or more, years had perished. The result was that the courses of bricks were lying on dry sand, and it was possible by using a 7-lb. hammer to get a " swing " on the main walls in the nature of a pendulum.

I came away feeling that the District Surveyor, Mr. Perkins, was fully justified in calling for the destruction of the house. But the great utility of the building and its perfect equipment, no less than its æsthetic and antiquarian interest, made it very desirable to do the utmost that could be done to save it. I was convinced that it could not only be saved by the application of the grouting machine without the removal of a brick, but that when the work was completed the structure would be transformed into a monolith, and rendered immensely stronger than it had ever been, without the smallest alteration in its appearance.

I reported to this effect and asked permission to make an experiment on a small portion of one of the walls. But to do this it was necessary to get from the Surveyor a postponement of the order for demolition. I therefore called upon him immediately. He had no experience of the grouting machine, and had never seen one, but on my assurance that I would ask for nothing that might increase the danger, or imperil his position and reputation as District Surveyor, and that I wished him to watch the operation, he very kindly deferred the notice for a fortnight.

My next step was to send to Messrs. Thompson & Sons of Peterborough, who had both men and machines at liberty, and after ten days' work we all agreed that the experiment was a great success. Beginning at the lowest course of bricks (after furnishing proper footings), we grouted up all the walls course by course. The timber framing we removed piecemeal as the work proceeded. Thus the walls were gradually strengthened from floor to floor. When we got to the roof, a difficulty presented itself. The parapet was only 9 in. in thickness, and I had previously never dealt with such thin work; but a very useful suggestion was made by the foreman, which overcame the difficulty. By the time the process was finished no one would have known that anything had been done to the house, so little had its appearance of age been altered.

Within five or six weeks Mr. Perkins withdrew his order to pull down; in five months the saving of the house was completed; within six months the nursing staff, much to their delight, were again installed in their beloved home.

Mr. Thompson with his representative Mr.

Ferrar carried out the repairs in a most able manner, whilst the men worked with great enthusiasm to save the building and to keep down the expenses. The approximate cost of the grouting was £420. The removal of the timber cost £35. To this must be added the cost of removing and replacing the old oak panelling, to avoid staining the wood—namely, £108. The total cost was therefore £563 instead of the £5,000 or more which would have had to be spent if the building had been demolished and rebuilt.

On the completion of the work, the committee of the hospital very considerately wrote to Messrs. Thompson, expressing the cordial thanks

"of our committee for the skill and energy displayed in saving this old house for us. It seems to us to have been a great triumph for the grouting process, and both on the score of economy to the hospital, and of interest in the preservation of old houses, we congratulate you on the success which you have achieved.

"Again thanking you,
"We remain, Dear Sirs,
"Yours faithfully,
(*Signed*) "ARTHUR LUCAS, *Chairman.*
"JOHN MURRAY, *Vice-Chairman.*"

This is the first instance of an old dwelling-house, condemned by the local authority, having been saved by the grouting machine, and it certainly ought not to be the last.

H.M. Office of Works, to whom I explained the system, have adopted it for the repair and saving of many old buildings, the property of the nation, and have several grouting machines constantly at work. My firm have used the method of grouting, or, as it is now termed in connection with large works, "the cementation process," on engineering work with as high a pressure as 4,000 lb. to the square inch. But in our work upon cathedral churches, towers, and such-like we never exceed a pressure of 60 to 100 lb. per square inch.

CHAPTER XVI

SAINT SOPHIA AT CONSTANTINOPLE AND THE CAMPANILE OF SAN MARCO AT VENICE

(1) Church of Saint Sophia, Constantinople

In January 1911, during one of my numerous visits to Constantinople, I was asked by the late Sir Edwin Pears, who had resided there for fifty years, if I were disposed to report on the condition of the fine Church of Saint Sophia, as to the safety of which he entertained some doubts. I at once agreed to do so and was then invited to make the necessary inspection by the office of the Efkaf, which corresponds to our Ecclesiastical Commissioners. I was accompanied by the architect, and the Minister of the Efkaf—Kemaledden Bey—on my first visit, and a week later I made a minute examination of the fabric with one of his assistants.

I had not the pleasure of meeting Signor Mongeri, who was not at that date in the city, but I had the good fortune of discussing the subject with Sir Thomas Jackson, Bart., R.A., whose able report on the building I had the privilege of perusing.

I found that serious movement had taken place in the piers, columns and arches. The church consists of four great arches which carry the large dome, together with side aisles and a fine narthex at the entrance. The arches are distorted, and the pendentives instead of curving outwards are actually leaning inwards. Some of them indeed no longer perform the functions of an arch. Portions of the frescoed dome or roof have been nipped and flaked off, and have fallen ; fillets or " tell-tales " which had been fixed were cracked ; some of the latter which were strips of glass, had broken through and had fallen. All this indicated serious movement, and I reported that no time should be lost in applying remedial measures for the safety of the building. However the Great War came and no steps were taken to repair the damage. For this purpose the grouting machine should be applied throughout the church to render it monolithic ; and the greatest care should be taken to avoid the removal of the mosaics ; in fact nothing should be done to deprive the structure of its venerable character and appearance. The movement of the dome should be arrested and it should be rendered self-contained.

Unless the more urgent repairs are carried out, the fabric may fall at any time, exposed as it is to earthquake shocks. But one of the first operations should be the timbering up of the four great arches and pendentives, and the centring of the dome.

This Cathedral was built and consecrated as a Christian church, but afterwards, falling into the hands of the Turk, was transformed into a mosque. Is it too much to suggest that it might be maintained for the use of its original worshippers ?

(2) The Campanile of San Marco, Venice

I have visited Venice many times during past years, and have always taken a special interest in the Campanile of San Marco. It was erected in A.D. 888, and had stood for one thousand and fourteen years, when it fell at 9.52 a.m. on July 14, 1902, providentially without causing loss of life or limb.

The structure was square on plan with an inclined passage on the inside of the external wall, and a horizontal landing at each corner. The height was 322 ft., and it was built on a forest of piles driven into the mud, so closely packed together that it was impossible to insert an additional timber. This foundation consisted chiefly of fir, but in places oak was also employed by the original builders.

It is stated that Venice gradually subsides to the extent of four inches in a century, but the sinking of the tower seems to have been about half this.

The conditions which caused the disaster were numerous and the result was not altogether unanticipated. It was seriously cracked from top to bottom, and tied together with iron rods. Yet in Venice, as elsewhere, the public mind is not given to nervousness about the stability of buildings. If a structure has stood for centuries it is seldom believed that there can be any particular reason why it should fall. Often, in our own country, the much needed repairs have been postponed until actual danger was imminent. At the present time many of our cathedrals and churches are in urgent need of repair. St. Paul's fairly heads the list of these. Others, such as Winchester, have been saved in time. There are, therefore, lessons to be learned from the fall of the Campanile.

It appears that this tower had been struck by lightning on more than one occasion. This was doubtless due to ignorance of the fact, which electrical science has since made clear, that proper "earths" should always be made by the copper lightning conductors. Other causes, however, had been at work to bring about the sad destruction of this fine edifice. The custodian who lived on the ground floor of the Campanile had surreptitiously enlarged his rooms by cutting out a considerable portion of the main wall, and thus seriously reducing the size of the supports. But an even more important factor was the existence at regular intervals of certain urinals in the passage. These had been neglected for centuries, and the sewage had permeated the walls, which were built in brick with lime mortar, to such an extent that the lime had been destroyed and the whole tower consisted simply of bricks lying on sand, without any proper cohesion.

In 1894, on the occasion of one of my visits, I was much alarmed by what I saw, and was on the point of writing to the Italian Government to call their attention to the danger of collapse. But I was informed that all the ecclesiastical buildings were under the care of the well-known and able engineer and architect Signor Saccardo. I therefore refrained from writing as I feared that I might be thought guilty of interference with those in charge, but I shall never cease to regret that I did not carry out my original intentions. I wrote, however, to a friend in the City of London explaining to him, in an ordinary and casual letter, what my fears were, and told him that in my judgment the Campanile would fall within ten years. Eight years later, in 1902, just as a testimonial was about to be presented to Signor Saccardo on account of his constant and careful control of the buildings under his supervision, the tower fell, and the unfortunate architect was so affected that he died, it was said, from a broken heart.

On the morning of the catastrophe the cracks in the tower showed signs of opening, and the custodian and all others in the building had sufficient time to leave the structure. In the meantime a large crowd assembled in the Piazza and saw it fall, and photographs were actually taken at the very moment of its collapse. The extraordinary thing was, that it did not fall on to the adjacent buildings, but on to its own foundation, leaving a great pyramid, or perhaps I should say a great cone of debris, consisting of dry bricks and dry sand with no cohesion between them.

Our old gondolier, Giovanni Padovane, who died at the age of eighty during the bombardment of Venice by the Germans, described to me in touching language "the merciful protection by God of our dear Cathedral of San Marco by not allowing a fragment of the tower, when it fell, to injure the church, although the angel from the summit, in falling, blocked the entrance nearest to the Campanile."

In one of his last letters this old friend of our family concluded in these touching words:

"Pray accept my salutations and receive again the good wishes, and the kisses on your charitable hand: when I do death, your name will be on my lips, from your old and humble gondolier

"GIOVANNI PADOVANE."

Under the care of Count Grimani, the Sindaco or Mayor of Venice, the names of whose ancestors occur in the city annals for six centuries or more, immediate steps were taken to rebuild the tower. The original piles were examined, and were found to be in excellent condition and undisturbed. Count Grimani very kindly presented me with specimens of the old oak and fir, embossed with the official stamp of the Municipality, both of which are as hard and firm as when first driven down a thousand years ago, thus showing that no defect existed in the foundations.

The architects therefore decided to leave the original five lowest masonry courses of the tower intact and to surround the existing pile foundation with a much increased area or barricade of piles on all four sides, in the form of a square. These timbers, 3,000 in all, are chiefly of oak about 8 in. in diameter and 15 ft. in length—more than double the length of the old piles. They are driven close together from the outside towards the centre, so as to compress the underlying clay and give not only additional support to the old foundation, but increased bearing area for carrying the load of the replaced tower. The weight of the latter has, in redesigning, been reduced by 3,000 tons, while the area of the timber foundation has been more than doubled.

All the important fragments of the tower, its bells and the golden angel from the summit, and also the remains of the adjacent loggetta with its statuary and bronze gates, have been carefully preserved. The statue of the Madonna, which was broken into 1,603 fragments, has been so cleverly restored that it is difficult to realise that it had been so seriously damaged. This feat recalls the piecing together of the celebrated Portland Tazza vase in the British Museum, which was smashed to fragments by a lunatic in 1845.

Before the rebuilding of the masonry courses upon which the brickwork stands, there arose what was known as the "battle of the five steps" which gave rise to a great discussion throughout Italy. That *five* steps had existed is certain, but it is also certain that only *three* were visible above the pavement of the Piazza, the other two having vanished out of sight owing to the general sinking of Venice, and the movement of the tower itself. The pavement of the square had, in course of ages, been levelled up. To ordinary readers it might appear somewhat immaterial whether three steps or five should be reproduced, but to the Italian mind, in which sentiment and love of the antique are pre-eminent, the question was all-important. After an immense discussion it was decided that five steps should be constructed, and five steps have accordingly been constructed, and are visible to all who visit the Piazza.

CHAPTER XVII

THE STATE OF ST. PAUL'S CATHEDRAL

VISITORS to the City of London naturally make one of their first pilgrimages to its great Cathedral. On few of those who do so does it fail to make a lasting impression. Its dimensions, the height and magnitude of the Dome, the Ball, and the surmounting Cross, are singularly imposing. And the stern, sombre gloom of the masonry, mainly attributable to London smoke, deepens its effectiveness. Moreover, it is—as no English visitor can forget—not only a grand church, but an Empire's mausoleum, in which many of our noblest have been laid to rest. And, beyond its architectural and sepulchral greatness, the Cathedral of St. Paul's is profoundly impressive, because it stands at the centre of the greatest Empire the world has ever seen, as a witness to the faith of a leading Christian nation.

Yet this magnificent monument is to-day in danger, and a few words of explanation will enable my readers to understand the situation. To the man in the street, St. Paul's has such an appearance of solidity and weight, and good honest work, that he passes on with a feeling that it is imperishable, and that it is not only "good enough for his time," but ought to stand for ages to come. Yet a public statement was recently made that it might be necessary to close the Cathedral, and even as these pages are being corrected for the press a fresh controversy has arisen as to the effect which the construction of a new bridge over the Thames might have upon the stability of St. Paul's.

What is the matter with the fabric? Why did Sir Christopher Wren give it a probable life of only 200 years? When I was consulted in November 1912 by the Dean and Chapter on the state of the edifice, I felt that it was a matter of national importance not only to answer these questions thoroughly, but to secure the future safety of the Cathedral, if that could by any means be done. There have been three churches on this site, including the present one. The second Cathedral was a fine Gothic church with a very high spire, some 600 ft. It suffered many times from conflagration and lightning, and was finally destroyed in the Great Fire of London. In the year 1668 Wren was instructed, by Dean Sancroft, to prepare designs for an entirely new building. Among the many difficulties which he had to face was the disposal of the ruins and rubbish of the burnt Cathedral. In the great fires the practice was not to attempt the removal of the debris, but to level it down and build upon it. For instance the present surface of Cheapside is 18 ft. higher than it was in Roman times, and the tower of Bow Church rests upon the Roman pavement. It will be seen later how the existence of all this debris affected the building of the present Cathedral.

My first report was called for in consequence of a proposal to construct an underground tramway and station near the end walls of the Choir of St. Paul's, and far below the foundations. The project was withdrawn owing to great opposition ; but the grave state of affairs revealed by the investigation called for a second report. I will attempt to summarise my conclusions as clearly as I can.

The building is cruciform in plan. The Nave is flanked by north and south aisles ; so also is the Choir. Over the centre, where Nave and Choir meet, and where the Transepts branch out to the north and south, stands the great Dome. A reference to Fig. 18 will show that there is an internal dome visible from the floor of the building, resting at about the level of the Whispering Gallery on a circular wall, which transmits the weight of this internal dome to the arches and piers below. There is also an external dome constructed of timber and lead ; and this it is which is visible from all over London. The external dome is similarly carried by another circular wall on the same level ; and the intervening space between these two great concentric walls is divided by thirty-two buttresses into a smaller number of chambers, each 10 ft. by 7 ft. On Fig. 20 these buttresses are shown projecting beyond the outer circle of stone much like the teeth of a large cog wheel in plan. Between these two domes comes the great cone of brickwork which carries the masonry of the Lantern, which in its turn bears the weight of the Ball and the Cross.

Each of the thirty-two chambers can be entered

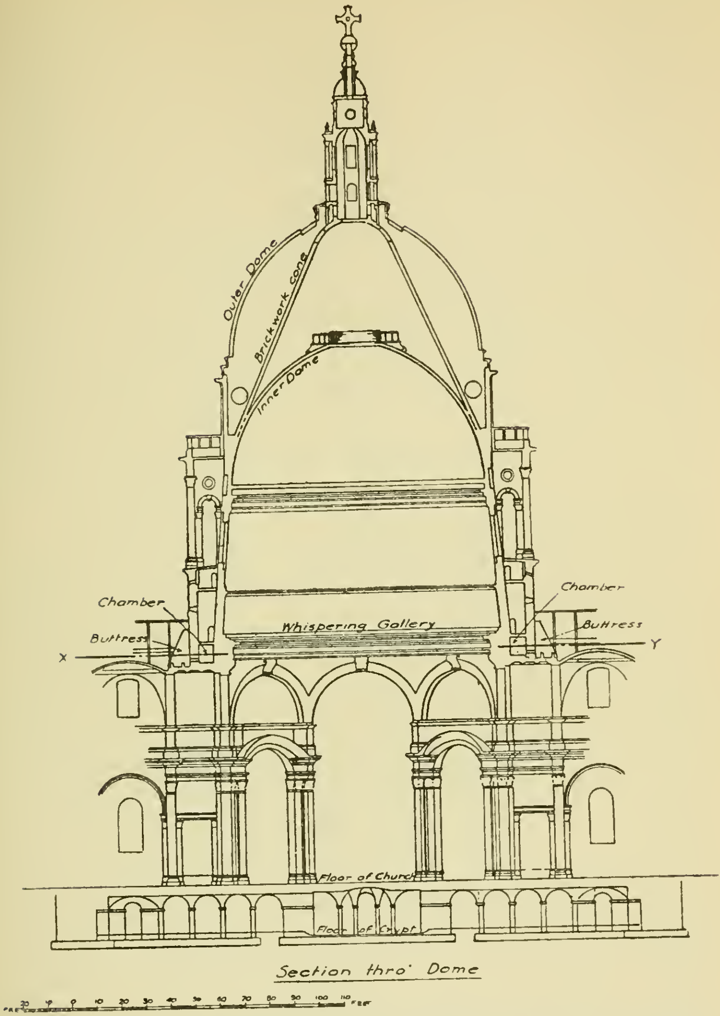


FIG. 18.—ST. PAUL'S CATHEDRAL: VERTICAL SECTION SHOWING THE INNER AND OUTER DOMES, THE GREAT BRICKWORK CONE CARRYING THE MASONRY LANTERN, THE BUTTRESSES AND CHAMBERS AT LEVEL OF WHISPERING GALLERY.

only through a small aperture in the main wall (which is 4 ft. in thickness) 13½ in. in width and 16 in. in height. The mode of entrance is peculiar : one cannot go through on hands and knees, since the height is so limited, nor can one wriggle through. The method is that by which a baker places his loaves in an oven. A plank 12 in. in width is held level with the bottom of the aperture, the visitor lies down on the plank, and drawing in his arms and knees is pushed through into the chamber. Inside there is no light nor ventilation, and nobody can remain for more than a few minutes. Once, indeed, a man stayed in too long and became so heated that he was too large to go back. Buckets of water had to be thrown over him to cool him down and thus reduce his size before he could be extricated. He strongly objected to going in a second time.

In order to ascertain the condition of the fabric, it was necessary to enter all these thirty-two chambers and to take photographs of the walls.

The depth to which the foundations had been carried was very shallow—only 4 ft. 6 in. below the floor of the Crypt and 12 ft. below the surface of St. Paul's Churchyard. The warehouses on the opposite side of the street are carried down 25 ft. ; and the sewer in Godliman Street runs 35 ft. below the street level ; in each case wet gravel and quicksand were encountered. To make the Cathedral secure against future buildings and excavations it should undoubtedly be underpinned, or carried down throughout into the Blue London Clay, otherwise the quicksand on which it stands may be drawn away. But much else calls for attention before this serious and difficult work can be undertaken.

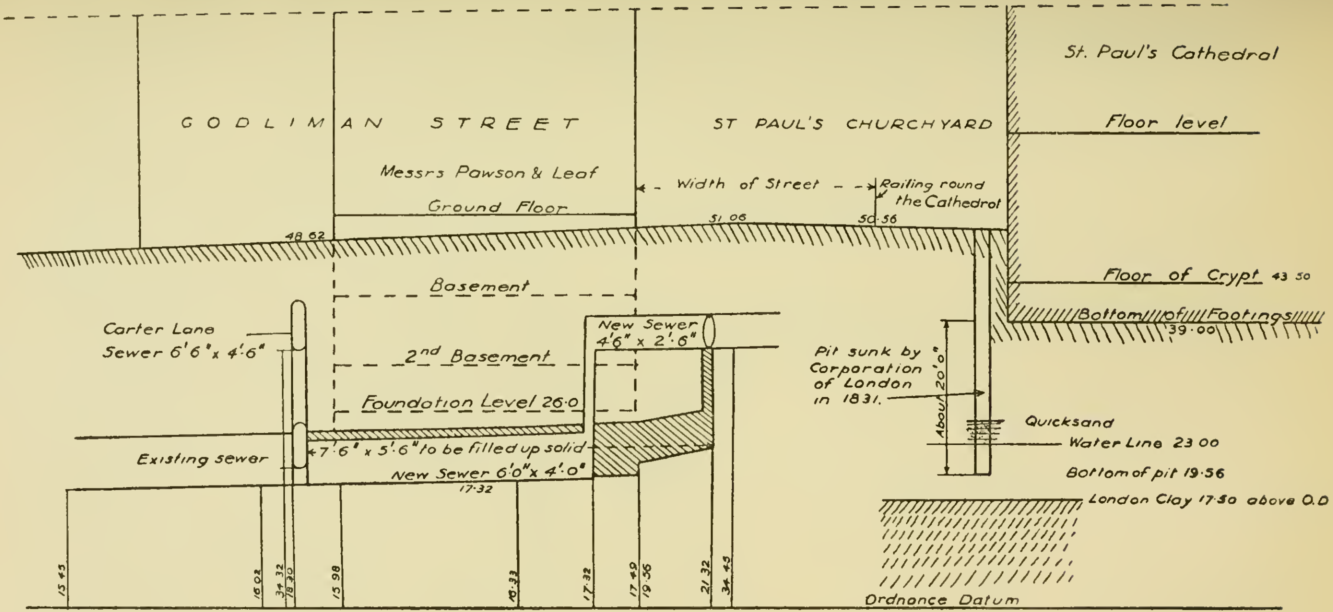


FIG. 19.—LONGITUDINAL SECTION FROM ST. PAUL'S TO GODLIMAN STREET SHOWING COMPARATIVE DEPTHS OF FOUNDATIONS OF CATHEDRAL, AND ADJACENT BUILDINGS AND SEWERS; ALSO DEPTH OF THE PIT OF 1831.

The Dome of St. Paul's is carried (see Fig. 21) on eight piers. In addition to these, four large bastions were provided to take some of the weight. It has, however, been ascertained that, owing to movements and cracks, these latter have broken away and do not assist the piers. The weight of the Dome at the bottom of the footings has been estimated at 60,000 tons or about 7,400 tons on each pier. Now the masonry of these piers, which any visitor to the Crypt can see, seems at first sight to be of excellent Portland Stone, apparently capable of carrying almost any load; but the inquiry brought out the startling fact that this fine masonry is only a thin veneer, in some places not more than 4 to 6 in. thick, and that the interior is filled in with badly executed rough rubble.

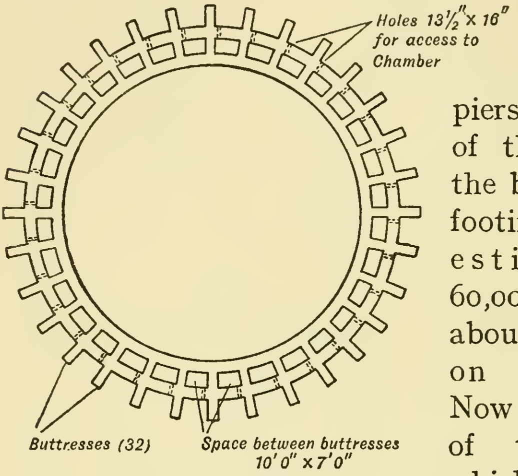


Fig. 20.—HORIZONTAL SECTION AT X-Y OF WALLS CARRYING DOME (see Fig. 18) SHOWING BUTTRESSES AND CHAMBERS AT LEVEL OF WHISPERING GALLERY.

The piers at Crypt level (see Fig. 22) are approximately 43 ft. in length by 20 ft. in width, with an average thickness of Portland stone veneer of 12 in. We are led to the conclusion that a kind of large rectangular bath was formed into which lime was thrown, and into this lime the stone debris from the former building was dumped anyhow without any attempt to bed the material. Just as a child throws his bricks into the box without arrangement, so did the builders throw the various materials into the framework of the piers. Lumps of Purbeck marble, Caen stone, Bath and sandstone bricks lie there mixed up promiscuously together. Some of them could even be moved between finger and thumb.

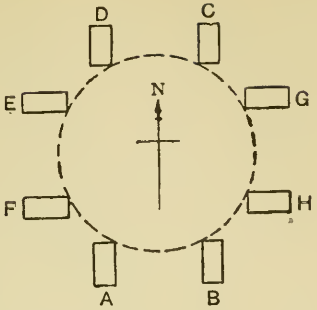


FIG. 21.—PLAN SHOWING PIERS OF DOME FROM REPORT OF AUGUST 1907.

The Pier A has descended bodily $6\frac{1}{8}$ in.
,, B ,, ,, $4\frac{5}{8}$,,
,, C ,, ,, $3\frac{1}{4}$,,
,, D ,, ,, $3\frac{5}{8}$,,
,, E ,, ,, $3\frac{3}{8}$,,
,, F ,, ,, $2\frac{5}{16}$,,
,, G ,, ,, $2\frac{5}{16}$,,
,, H ,, ,, $2\frac{5}{16}$,,

All the eight piers have at some time or other moved, the degree of subsidence varying from 2 to $6\frac{1}{2}$ in. Some have subsided on the "toe," others on the "heel" of the pier, and enormous strains have thus been put on the superincumbent arches. Frequent repairs have been effected at various dates.

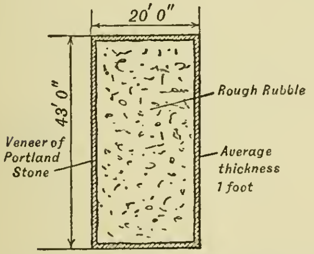


FIG. 22.—HORIZONTAL SECTION OF PIER 10 FT. ABOVE FLOOR OF CRYPT.

In 1831 the Corporation of London proposed to construct a deep sewer on the south side of the Cathedral from Watling Street to Godliman

Street, and they had a shaft sunk at the foot of the steps of the South Transept. This pit was excavated to a depth of 31 ft. below the street level, no less than 20 ft. below the foundations of the Cathedral, and was described in the reports of the date as being, for the first few feet, in gravel, water, and dangerous quicksand, which could not be retained in one's hand. This pit was a very great danger to the Cathedral, for out of it "hundreds of tons" of this quicksand or silt were removed by steam pumps. A strong protest was made by many eminent engineers and architects, amongst them Telford, Brunel, Acton, Rennie, and Cockerell, pointing out that a grave risk was being incurred. "Already," they declared, "damage may have been occasioned."

The sewer was therefore abandoned and the shaft filled up, but great damage and dislocation had been caused to the building. The eight piers carrying the Dome have been badly cracked, the four large bastions have been sheared off and are not now carrying their load, and of the thirty-two buttresses which were intended to distribute the weight on to the piers and walls, twenty-three are badly fissured, and, in some cases, practically sheared. The drum of the Dome is also cracked, and when the Dome was plumbed in August 1901 by Mr. Somers Clarke it was found to be $4\frac{3}{8}$ in. out of the perpendicular in a south-westerly direction. We measured this again in March 1913, and found that the divergence had increased to $5\frac{3}{4}$ in.

In view of the gravity of all these indications

I suggested at a meeting of the Dean and Chapter that they should call in some leading engineer or architect to whom all the facts and measurements should be submitted, together with the various reports and my own personal evidence. In reply to a question by the Dean, I recommended either the President of the Institution of Civil Engineers, or the President of the Royal Institute of British Architects, with the result that I was instructed to see the then President of the Institution of Civil Engineers, the late Sir John Wolfe Barry, F.R.S.

I accordingly interviewed Sir John Wolfe Barry, and he asked me what the business would entail. I informed him that besides the perusal of all the various reports, a careful examination of the whole fabric would be necessary. After much consideration he said, "Fox, I cannot undertake what you do, climbing vertical ladders 80 ft. in height, getting round the cornice and examining the thirty-two chambers round the Dome, the entrance to each of which is so small that a man of my size and age could not enter. But I will tell you what I will do: I will send an engineer of wide experience who has done much work for me and he will do all that is necessary and inform me, and I will issue a report on the results of his visit." This engineer was Mr. R. C. H. Davison, M.Inst.C.E., whom I had never seen previously. He spent eleven days upon the investigation, which was made with the utmost care, but he very properly never gave me the smallest indication of the result of his visit. He duly reported to Sir

John Wolfe Barry, and that gentleman, I believe, in his turn reported to the Chapter.

I have not seen either of the reports; but when the work was done Mr. Davison wrote more than once to me, and extracts from his letters are sufficient to indicate the conclusions to which he had come.

The following paragraph from our Committee to the Dean and Chapter shows the conclusion at which we had arrived.

Extract from Report of September 3, 1913

"In the judgment of your Committee, the present condition of the building is such as to require the immediate strengthening of the supports of the Dome, the grouting up of piers and masonry generally, and the insertion of bonding stones, also the removal of iron cramps without waiting for more careful observations. Before this can be safely carried out, the arches must be supported on centres and the piers strutted.

[*Signed*] "MERVYN MACARTNEY, *Chairman.*
R. C. H. DAVISON.
FRANCIS FOX."

The proper sequence of operations in repairs of this character is, as I have often said, as follows:

No. 1. To shore and timber up the walls, and to centre the arches, in order to relieve them of as much weight as possible, and also to prevent any broken pieces of stone from falling.

No. 2. To wash out with water and grout up with cement the masonry or brickwork, rendering the whole mass monolithic, so that any operations on the foundations may be as free from risk as possible.

No. 3. To replace broken masonry and to insert the necessary bond stones.

No. 4. When all this has been done steps may be taken to strengthen the foundations.

It is evident that to alter this sequence in any way is to court disaster. Not a stone should be moved nor cut open, even to remove the old rusty iron ties, until all grouting is done.

If reference be made to *The Illustrated News*, January 11, 1913, it will be seen that for years past cracked stones have been removed and replaced by new stones, and these again in some cases have been crushed. The fact is that the masonry is severely overloaded, and the only way in which the material can call attention to the danger, is to flush or flake off pieces which either fall into the church or are removed before they fall. On one of my visits I found on No. 1 Pier, some 30 ft. above the floor of the church, a large piece of Portland stone which had been flaked off, and which was fortunately caught by one of the ornaments. I lifted it on to the scaffold and measured it. It was 20 in. in width, 24 in. in height, and had an average thickness of 2 in. The fracture was quite new, not a speck of dust nor soot was present—and it proved recent movement. To replace such a broken stone does nothing to take the load, which can only be carried by the remaining portion of the fractured block. Consequently the bearing area of the masonry of the piers is being constantly and automatically reduced. The result, if this process continues, is inevitable.

Nor is this the only cause of the increasing weakness. During the redecoration of St. Paul's, a few years ago, large panels, some inches in depth, were cut in the great arches carrying the Dome in order to give shadow. These arches were already overloaded and the removal of the stone for the panels increased the load on the remainder of the masonry. It was noticed that there was a metallic ring each time a blow from the mason's hammer was struck, and the fragments flew off in all directions as from a gun. This proved that the stones were under heavy pressure. In my opinion it was most undesirable and dangerous, thus to reduce the strength of these arches. Everything possible should be done to increase their strength, and at the same time to reduce the load. All other work should be left until it can be carried out without risking the safety of the building.

To indicate movement in cracks, cement fillets or tell-tales should, in all cases, be fixed. The method of using stamp paper for this purpose is inaccurate and unreliable.

The proper method of carrying out the repairs "above ground," difficult as it is, is comparatively clear. But the problem of strengthening the foundations is more difficult. The first thing to be done was to ascertain whether in fact quicksand exists underneath St. Paul's Cathedral. The opinion has been confidently advanced— that there is *no* quicksand under the Cathedral. I was, myself, equally confident, from my extensive experience in sinking shafts for the tube railways, that it did exist ; and this belief of mine was subsequently confirmed by the excavations on the Post Office site, particulars of which follow. But proof of the conditions actually beneath St. Paul's was obtainable. Excavation close to the Cathedral, as at Winchester, was impossible, owing to the graves ; but I received permission to sink an artesian well in the Crypt, and by means of an electric light lowered down the well, we not only proved the existence of water, but could actually see it *flowing* in the direction of the Thames.

The next thing to do was to find out whether by means of grouting, the beds of gravel, clay, and quicksand could be made solid without actual underpinning. Permission was obtained from the authorities to try the experiment of grouting the subsoil on the vacant area near the Cathedral, formerly occupied by the Post Office, at the west end of Cheapside. Some tubes known as Abyssinian wells were driven down to the clay, and a powerful machine was employed for forcing in cement. A pressure of 400 lb. to the square inch was used, and inch by inch the tube was drawn up, thus exposing the layers of sand and the gravel to the injection of the cement.[1]

We obtained very satisfactory results on the Post Office site. The gravel was formed into solid conglomerate, the beds of clay were permeated by bands of cement, and even the quick-

[1] We have recently been using a much higher pressure in South Africa in the cementation of fissured rock with complete success, the pumps being capable of exerting a pressure of 4,000 lb. to the square inch.

sand in the vicinity of the tube was transformed into a fairly hard sandstone. If further experiments and tests yield similar results, it would seem that St. Paul's Cathedral can be safely founded on the London Blue Clay without the expense and risk of actual excavation.

Besides carrying out this experiment, we made an actual excavation from the surface down to the solid Blue Clay, a total depth below street level of 42 ft., in order to ascertain the state of the strata. By ordinary excavation the water level was reached at a depth of 32 ft. At that point progress was arrested by the presence of this water, which exactly confirmed the experience of Sir Douglas and myself when we constructed the forty-six shafts for the tube railways of London. The aid of a diver was secured from Messrs. Siebe & Gorman in the person of our tried and trusted friend the late Mr. William Walker, who did such magnificent work under Winchester Cathedral. He continued the excavation under water down to the Blue Clay, proving the existence not only of water, but also of gravel and quicksand for a depth of 11 ft. I, myself, went down in the dress to corroborate all that he had reported. Both he and I noticed particularly that the vibration caused by motor omnibuses and heavy motor vans was more perceptible at the bottom of the excavation in the quicksand than at the surface, where the gravel is dry and is above water level.

The effects of vibration upon the Cathedral in its present condition are, indeed, considerable. An independent scientific committee was appointed to report on this particular question. I called their attention to the chattering of the large mahogany doors of the Library whenever a motor 'bus went by. A leading authority stated that this was the result of the current of air passing through the doorway. This was incorrect, as I demonstrated by means of a lighted match. There was no current of air sufficient to produce such an effect, nor indeed to deflect the flame from the vertical. It is disquieting to realise that the vibration is even greater underneath the foundations than it is upon the surface.

Almost all the preceding facts have been published, at one time or other, by the Cathedral authorities in *The Times* and other public newspapers, and now a Committee is sitting—under the Presidency of Sir Aston Webb, P.R.A.—including three civil engineers of high standing and wide experience, their task being to report upon the Cathedral and its condition, with proposals for making the fabric secure. We can only wish them complete success in their arduous work. They have, in their interim report (see *The Times*, January 1922), stopped all repairs—and have ordered the removal of all loose masonry inside the Cathedral. Meanwhile the steelwork, which has proved useless, has been scrapped.

We are now awaiting the Committee's final report. But, as I am the only survivor who has been actually *in* the quicksand so close to St. Paul's as the Post Office site, and who is thus acquainted beyond all possibility of mistake with the real nature of the foundations of the

Cathedral, I have thought it right to publish the main facts as I know them.

Our work on the Post Office site had a somewhat amusing consequence. It is well known that on the ground in question numerous Roman objects have been, and no doubt still remain to be, discovered. It was reported that a Roman Column had been found, and it was surmised by the learned that it probably had carried a bust of Juno, or Minerva, or some other goddess. However, it was found to be of much more prosaic origin, and was, in fact, one of the columns produced by our grouting experiment. It was a modern parallel to the discovery by Mr. Pickwick of the stone whereon was carved—

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It may interest the reader to know how the Dome is plumbed. This is a delicate task, even if the necessary apparatus is provided ; but our first attempt ended in an amusing, or rather an annoying, though instructive fiasco.

Whenever I have found it necessary to plumb the shafts of tunnels or mines I have done it in the following way. The requisite length is obtained of hard-drawn german-silver wire $\frac{1}{40}$ in. in diameter. Such a wire has no tendency to stretch, or to develop torsion. A heavy weight or plumb-bob of 28 lb. is attached to the lower extremity of the wire, and the upper end is fixed by means of a very delicate arrangement which is capable of allowing lateral movement. The tendency of the bob is to move as a long pendulum, with a period of oscillation of 9·79 seconds. In order to bring it to absolute rest, it is allowed to hang suspended in a bucket of tar, the viscosity of which very quickly stops the oscillation.

At St. Paul's, the necessary orders were given, and we assembled under the Dome one evening after the public had all left. An assistant was up in the Golden Gallery, 315 ft. above the floor of the church, and his instructions were to lower the wire for attachment to the "bob." As the height was too great for communication by word of mouth, a code of flash signals by hand-lamp was arranged. We waited for some time, and then noticed a kind of wriggling snake slowly and noiselessly coming down through the darkness from above. At once I realised we were in for a failure. Instead of a wire it was a fine rope, which would be both elastic and subject to torsion and unravelling. But no sooner had it reached the ground than the assistant at the top let the end slip through his fingers, and the whole length of cord fell on to our heads in a tangled mass. We had to disentangle it, coil it, and send it up by a second messenger. After some little delay the assistant at the top, wrongly imagining that the operation was finished, released the cord a second time and again it fell on our devoted heads in another tangle. Once more we sent it up, by the same unfortunate messenger, and at length we had the satisfaction of knowing that at least we had a cord from top to bottom, although it was not of the right material.

A fresh series of troubles now confronted us. The "bob" was only 7 lb. in weight instead of 28 lb. To avoid the possibility of tar being splashed on the marble floor, the bucket had been filled with water. The "bob" began to spin with great rapidity and the cord to lengthen. The centrifugal force threw the water all over the floor and the oscillation was not retarded. It was suggested that a handful of sawdust in the water would offer some resistance to the spinning, but the plumb-bob showed no intention of stopping and threw both water and sawdust on to the floor. The cord elongated, the bob reached the bottom of the bucket and finally fell like a tipsy man on to its side, and all our efforts were defeated.

We wisely decided to defer the task for two or three weeks until I could obtain the proper tackle: to wit, a fine piano wire which would neither stretch nor rotate, a 28-lb. plumb-bob and a bucket of oil, in which it would come to rest, and a proper and accurate windlass on which the wire could be coiled.

We met again, and this time our efforts were crowned with success. The pendulum movement was overcome, there was no tendency to rotation, and we had now obtained a vertical and quiescent wire, the exact position of which we were able to record. The divergence from the centre of the Dome was found, as I have already stated, to be $5\frac{3}{4}$ in. as compared with the results recorded a few years earlier by Mr. Somers Clarke of $4\frac{3}{8}$ in.

PART III

VARIOUS

CHAPTER XVIII

MINING

It has been my good fortune, during a long business life, to visit nearly all kinds of mines, with the exception of those that produce platinum, quicksilver, ruby, and nickel. The others with which I am familiar include mines of gold, silver, diamond, coal, tin, radium, copper, iron, salt. But I shall only allude briefly to those of coal, iron, and tin, with which I have been closely connected.

Coal.—These deposits are chiefly reached by vertical shafts, some of which exceed 1,100 yards in depth, while others are less than 150 ft. Sometimes the mineral is reached by adits or levels driven from the daylight into the sides of hills or mountains. The deepest shafts in England are at Wigan, where those of the Rosebridge Collieries are 1,100 yards deep, and the cages travel at the high speed of 50 miles per hour. The thickest seams are in Staffordshire, in what is known as the "ten-yard"—or 30-ft. beds. The thinnest seams in which I have been are in Ireland and were only 14 in. in thickness, and in these the travelling roads or galleries through which the coal is conveyed to the pit bottom were only 2 ft. 6 in. in height.

A curious result has followed from the deep mining in the neighbourhood of Wigan. The extraction of coal from several seams underneath one another has caused a great subsidence of the surface of the land, below the level of natural drainage, and has produced what is locally known as the "Lake District." The important Leeds and Liverpool Canal was originally on the surface of the land, but in course of years the towpath has had to be continually raised and runs now on embankments 20 and 25 ft. high or more.

The magnificent wealth of the coal deposits in Great Britain is likely to last for some centuries yet. It is frequently being increased in area by new discoveries, one of the latest being the coal-field near Newark and Doncaster which is believed to extend even farther than was at first supposed.

Iron Mines.—I was unexpectedly appointed as manager in 1872 to some important iron mines. I protested against undertaking work of this description, on the score of want of experience, but the chairman of the company said that this was not of moment, all he wanted was to have a man on the spot, not so much a mining engineer as someone he could trust to report everything truthfully to the Directors. This, of course, I could do by living in the neighbourhood, and I was able not only to keep the Board fully informed, but to acquire for myself the fullest familiarity with every mining question. This was of the greatest assistance to me later on in my profession as a civil engineer, especially in the ventilation of buildings and tunnels, and in the solution of great pumping problems, and in "winding" or raising from great depths large tonnages of mineral and rock.

When Sir Stafford Northcote was Chancellor of the Exchequer, he and a deputation of Members of Parliament decided to visit some good representative mine. Our mine was selected for this purpose as one of the deepest and most important in that particular district. The depth was 170 yards to the pit bottom. The seam was 9 ft. in thickness and on a fairly easy gradient to the "dip."

I was requested on Tuesday's "Change" to receive the Chancellor next day at 12 o'clock, and I at once wired to the officials at the mine to make the necessary arrangements. I telegraphed to the hotel to send a first-rate lunch for twenty-seven persons with the necessary waiters. They worked late and early, and when I arrived at the mines I found everything ready. The party consisted of the Chancellor of the Exchequer, several Members of Parliament, and leading iron-masters, numbering twenty in all. It was arranged for the lunch to be given, not in the engine-room at "Bank," but in one of the working places of the mine. The waiters refused to go underground, but were promptly "run in" to the cage, and then found it not so terrible as they expected. The ventilating fan was stopped and half a mile of the workings had been lighted with candles. The whole process of getting ironstone —drilling, blasting, breaking up—was explained, and then out of the deep gloom of the mine the party were ushered into a little bit of fairyland—

a working place draped all over with white calico and brilliantly illuminated by wax candles and candelabra. The tables, sumptuously furnished with flowers and glass, looked really charming. Sir Stafford told me it was the most impressive scene he had ever witnessed, and all went away delighted.

The officials, foremen, miners, and the boys then came in, in rotation, to finish the lunch. There was enough for 160 !

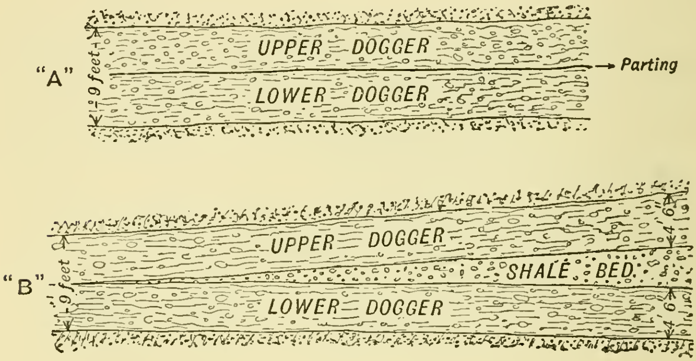

Fig. 23.

Our output of ore was at that time about 7,000 tons per week, nearly all of which was calcined in large kilns, in order to drive off the moisture and carbonic acid gas—a process which saved some 25 per cent. in railway freights. But unfortunately a few years later a change in the character of the seam developed which can best be explained by a rough sketch ; and in November 1882, after a long struggle for seventeen years, the work was brought to a standstill with a total loss of £150,000.

The seam consisted of "Upper Dogger" and "Lower Dogger," giving a total thickness of 9 ft., but as we worked to the "dip" these two beds gradually separated. The conditions shown in "A," where the two beds are separated by a "parting" no thicker than a sheet of writing paper, was replaced as shown in "B," by a shale bed of no value. Although the two Doggers continued to have the same thickness and same percentage of iron as before, the cost of mining was increased, and the average value of the ore was reduced. It was impossible to separate the shale (which was "less than worthless") from the good ore, since there was no free parting. Consequently the furnace owners found it more expensive to produce pig iron from the ore, and as the selling price of ironstone at the pit's mouth often did not exceed 3*s*. per ton, any reduction in price meant a heavy loss.

The only thing I now possess as the result of all our expenditure is a good but small specimen, 1½ in. in diameter, of a fossil of the Pecten Shell which is the distinguishing feature of the Pecten seam.

During my career at the mine an incident occurred which, had it not been for its serious results, would have been amusing. About 1876 a merchant in London came to ask us to design, order, and ship out to the Andes in Chili a complete mining plant for a silver mine. He brought us the order and the specification in Spanish, but we pointed out to him that we should not like to undertake the responsibility of translation. He saw the reasonableness of this, and took the documents away to be translated, and in the course of a few days returned with them in English.

We set to work—designed and ordered a very complete plant. The mine was high up in the Andes, so that every part had to be taken up by mules. Consequently the engines, boilers, and every subsidiary part had to be so designed that no piece should exceed 3 cwt. The shaft was ten degrees from the vertical, and the cage was to run on inclined rails. There were winding engines for the shaft, hauling engines for the underground planes, pumping engines, boilers, guides, pulleys, ropes, wagons, and also the necessary buildings—all had to be perfectly complete to the last screw. We had it all put together at Messrs. Appleby's works at Leicester; tried in steam and tested, then carefully packed, shipped, paid for, and our work was done.

From the time the order left the mines, to the time when the long cavalcade of mules were toiling up the mountains, about two years had elapsed.

We heard nothing more about it until, some three years afterwards, I met the merchant by chance in Cannon Street, and I asked him how the machinery had answered.

He said: "What! haven't you heard?"

"No—not a word."

"Didn't you hear of the mistake?"

"No! what mistake?"

"Don't you recollect you declined to be responsible for the translation? Well, the man who translated it made a mistake in the transition from Spanish to English measurements, and forgot to divide by 2. The result was the cage was twice as long and twice as wide as it ought to have been—and it wouldn't go into the shaft! And everything was in like proportion. We couldn't use it—and sold the whole thing, lock, stock, and barrel, to an adjacent mine—and began again!"

Tin and Radium.—In 1908 I was informed that boxes containing rich radium ore were being forwarded to Paris from Cornwall, at a price of £200 for 150 lb. weight. It was to the laboratory of Madame Curie in Paris that these boxes of pitchblende were being regularly sent. After making the necessary inquiries I went to Cornwall, with my son the late C. Beresford Fox, and spent several days in digging amongst the derelict waste heaps from Trenwith Mine near St. Ives. We soon found lumps of very heavy ore which I sent to the late Sir William Ramsay, F.R.S., for report and analysis. He replied that it was pitchblende of very high quality, worth £3,840 per ton; since it contained 192 milligrammes of radium, each worth £20, to the ton. He offered to extract the radium from the samples. This he successfully accomplished, and I exhibited 6 milligrammes of radium worth £120, at the Conversazione of the Royal Society, May 12, 1909—the first time that British radium extracted from English pitchblende had ever been seen at Burlington House.

As the hospitals were unable to buy radium, and as war with Germany was not then thought of, we accepted an offer from leading people in Frankfort to purchase all the radium we had in stock, some £12,000 worth, and entered into a contract with them, by which they undertook to purchase the whole of our annual output for the next two years—about £40,000 worth a year.

Then the war broke out. In an instant the contract was annulled, and the Radium Company found themselves entirely without purchasers of the product—a very grave position. An appeal was made to the Government for assistance; we undertook to supply them with all the radium required for compasses, clocks, and watches with luminous dials. But the Government would not take it, although they purchased £250,000 worth of inferior radium from America. Nothing remained but to place the Company in the hands of a receiver. But we had the satisfaction of knowing that several British hospitals were supplied with our product, particularly the Middlesex Hospital, whose Professor of Radium informed me that it was the finest and purest radium they had ever used.

Mining Frauds.—Twice at least I have been instrumental in exposing an attempt to foist a worthless property on the investing public. In October 1885 I was instructed by a powerful syndicate in Lombard Street to go to the Continent to investigate what was considered to be a very rich deposit of red hematite iron ore. I asked my great friend, the analytical chemist, Dr. Stead, F.R.S., of Middlesbrough, to accompany me.

Our object was to ascertain the position of the property, its accessibility, and the character of the ore, and to obtain samples for analysis. At a meeting of the syndicate the day before our departure, the agent for the property was present, and laid on the table some very rich specimens of ore—one of which I asked and was given permission to take away in my pocket.

After a thirty-hours' railway journey across Europe Dr. Stead and I had to drive into the mountains by a carriage and horses, as far as a road existed. We then took horses and rode some few miles farther, until the mountain slope became too stiff even for riding. When we had walked another mile in drenching rain, we reached a place which the custodian of the property declared to be the site of the iron deposit, and we set to work at once to take samples of the ore, labelling and placing them in separate canvas bags. But neither Dr. Stead nor I were at all satisfied, and pressed the agent of the estate to take us to the place from which came the specimen I had brought with me. He seemed surprised, and said that it was a long way off, over the mountains. I told him it was absolutely necessary for us to see the place itself, and that we would return in two days if he would make arrangements to take us there. To our astonishment he replied that this was impossible, that the ore of which I had a specimen was not to be found anywhere in the neighbourhood.

Just then, a large bounding rock came rushing down the mountain-side and I had only time to shout "look out." It passed over us, but struck our excellent interpreter on the head and fractured his skull. We had the greatest possible difficulty in getting him down the mountain to the railway, and delivering him to his father and mother in Rome, where the former occupied the important post of Correspondent to *The Times*. I saw the announcement of his death three or four years later, no doubt accelerated by this accident.

On our return to London, a meeting of the syndicate was called to hear our report : and I need not say that the whole project collapsed and an extensive fraud was exposed, for which we received the cordial thanks of the members of the syndicate.

On another occasion I was asked to report on a silver mine in one of our largest colonies. The vein of ore was 30 ft. in thickness, and, having provided myself with 360 washleather bags, I proceeded to take a sample at every inch of the width. This called forth a strong protest from the owner, but I pointed out that it was proposed to work the whole width of the vein, and that it would be necessary to ascertain by analysis the average value of the entire deposit ; and I added that unless I was allowed to arrive at a correct result, I would not report.

This brought about a collapse of the whole enterprise. If it had been carried out, it would have caused the loss of the entire capital of the Company.

Mark Twain told an amusing story, which had no doubt improved by repetition. A mining venture had been started to drive a tunnel in the Sierra Nevada of the Rocky Mountains, into which scheme he had put some money. Year after year passed without the discovery of the mineral, and the shareholders were continually urged to find further capital for the undertaking. Finally he decided to go and see for himself what was being done. After three days in the train and two more on the top of a coach, they arrived at last in sight of the mine, and Mark Twain asked the coachman what was that extraordinary erection of timber on the side of the hill. The driver replied, " Wa'al, you see, the Company let a contract for so many hundred yards of tunnel to cut the lode. But before they had made the contract distance, the tunnel came out on the other side of the hill, so they built what was left of it on trestle work ! "

CHAPTER XIX

DIVING AND COMPRESSED-AIR WORK

ANY young man beginning the career of a civil engineer ought certainly to learn the work of a diver. Many years ago I took lessons in a tank at the works of Messrs. Siebe & Gorman, in the Westminster Bridge Road, where they would allow anyone with proper introductions to train, and not only did I benefit by their kindness, but both my sons went through the course, and held certificates of competence.

My first experience of diving in the sea was at Douglas, Isle of Man, when the late Mr. James Walker, the Manx Government Engineer, kindly asked me to accompany him on one of his visits under water, to examine the breakwater. There was a heavy gale of wind blowing and a big sea coming into the harbour, and it proved to be a most unsuitable day for our purpose. Notwithstanding the assistance of a diver, technically known as the "lady's maid," it was almost impossible to get into the diving dress on account of the heavy rolling of the barge. To make matters more difficult it was necessary before leaving the boat to put the leads, each weighing 40 lb., over one's shoulders ; to put on the boots, each with a sole of lead 20 lb. in weight, and finally the collar and helmet weighing another

30 lb. Thus laden it was a dangerous operation to get over the gunwale of the barge.

When thus fully equipped, the diver, going below the surface of the water, loses all this load, and by means of a valve in his helmet adjusts his weight to the same specific gravity as that of the water. He is able to go down and up with the greatest ease, and, in addition to this, finds the bottom of the sea a comfortable place for a midday rest. With the helmet resting on a rock, surrounded by seaweed, one may be lulled to sleep by the measured strokes of the pump.

When I reached the bottom, the sea was so loaded with sand and mud that it was impossible to see anything. We therefore returned to the barge, exhausted and nearly seasick with the motion, and gave up the attempt. Mr. Walker was afterwards appointed engineer-in-chief to the River Tyne Commissioners, and I accompanied him on his inspection of the north breakwater, which had been breached and overturned by a heavy north-easterly gale.

Very different was my experience in Constantinople, whither I had gone on behalf of the British Government to inspect the Quay Walls in Stamboul and Galata on the Bosphorus. I was then staying at the British Embassy as the guest of their Excellencies Sir Nicholas and Lady O'Conor, both of whom were somewhat nervous at the idea of my going under water without an English diver. As I could not postpone the work, I made the necessary arrangements without their knowledge, with an Italian diver, who could only speak a few words of English.

It was a lovely May morning, the water as clear as crystal and everything bright and sunny. I had fixed the time at 8 a.m., expecting that no one would be about at such an early hour ; but to my surprise I found a crowd of 500 Turks on the Quay wall at Galata waiting to see " the Englishman dive." I had to get into my dress in the boat, and so great was the excitement that the crowd almost pushed the front row of spectators into the Bosphorus. However, I had to see the thing through, and very soon found myself at the bottom of 43 ft. of water, in another world altogether.

A shoal of large fish 2 and 3 ft. in length, with beautiful iridescent fins, sailed majestically toward me and circled round the intruder on their domain. The shell fish were taking their morning constitutional ; the oysters were open ; the anemones were blooming in all the fullness of their beauty ; the lovely jelly-fish with their exquisite pink and green fringes came floating gracefully about us ; and the seaweed, not lying flat as we see it on the shore, but erect and gently waving to and fro in the current of the Bosphorus, looked for all the world like trees in a slight breeze of wind. A brilliant sun was shining and made the whole submarine landscape as light as day.

Two or three effects struck a mind trained to observe the world from a scientific point of view. Looking upwards I became conscious of the fact that nothing was visible above the level of the sea. Owing to the " skin " of the water, the underside of the surface was impenetrable to the eye. Anything floating on the sea, such as a steamer or our diving boat, was plainly visible from the keel upwards as far as the surface ; but there it stopped and nothing above that level could be seeen. A boatman in a rowing-boat passed over the place where I was standing. I could see the keel and the planks of the boat quite clearly, also the blades of his oars as he dipped them into the sea, but the portions of the oars from the blades to the rowlocks were apparently cut off.

Another curious effect I remarked. I had with me the Italian diver to carry my crowbar, hammer, and chisel. But owing to the three angles of refraction, viz. of the air in my helmet, the glass of the eye-pieces, and the water of the sea, I could not localise him. It was only by sweeping my arm round, and catching hold of his dress to attract his attention, that I was able to get what I wanted.

In modern dresses a telephone is fixed in the helmet which communicates through a switchboard in the diving-boat with any other diver. But on the occasion of my Bosphorus dive the only method of communication was to let our helmets touch and shout out what we wanted to say. Even this did not avail us much, as he spoke Italian and I English.

Once when lecturing at Eton College on diving, I had on the platform a fully equipped diver. He had the latest improvements in his helmet, which was fitted with a telephone. I had previously fixed on the ceiling of the hall a megaphone connected by wire with the telephone, and as he had a fine bass voice I had arranged with him to sing some nautical song with a roaring chorus, on my tapping three times on his helmet. This I did ; but no sound could be heard until I switched on the telephone to the megaphone, when, to the delight and surprise of the head-master and the boys, the deep bass notes of the chorus came roaring from the ceiling. Dr. Lyttelton, in thanking me afterwards for the lecture, said he had heard singing under many conditions, but that this was the most novel of all.

Compressed-air Work.—I have more than once referred in the course of my book to the use of the compressed air in tunnelling. Perhaps a brief non-technical description of the method will interest my readers.

When a tunnel is being driven through strata which are charged with water, an "air-lock" is provided which serves much the same purpose as a "water-lock" on a canal or river. When the lower gate of a water-lock is open to admit a boat which has to be raised to a higher level the pressure on the upper gate is such that it cannot be opened. The lower gate is then closed, and water is admitted to the lock from the higher level. This effectually fastens the lower gate, and the water level in the lock continues to increase, until it is the same height as the upper portion of the river. The pressure is then the same on the two sides of the upper gate, which can be opened without difficulty, to let the boat out on its journey up country.

In a very similar manner the action of the "air-lock" in a tunnel enables officials and workmen to pass from ordinary atmospheric pressure into a portion of the tunnel which is under greatly increased air pressure. A large steel tube 6 or 7 ft. in diameter with a length of 20 to 30 ft., resembling an ordinary Lancashire boiler, is firmly fixed in the tunnel and is provided with an iron door at each end, the door at the left end opening inwards, towards the tunnel beyond, that at the right end also opening inwards.

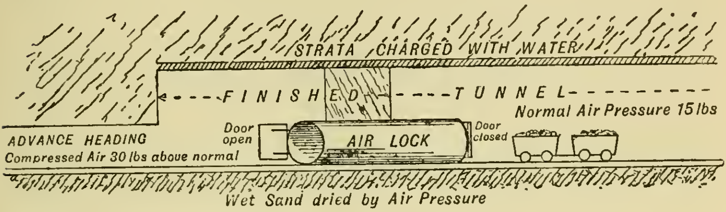

FIG. 24.

On going to work, the men enter this tube or air-lock through the near door. The pressure of the air inside is then the ordinary barometric weight of the day, say 15 lb. to the square inch on both sides, and the door can be easily opened. The door is then closed, and compressed air is admitted to the "air-lock" or tube, the pressure of the air firmly closing the near door, just as in the "water-lock" the pressure of the water closes the lower gate. The supply of compressed air is continued until the pressure is the same on both sides of the far door, which we will assume to be 30 lb. to the inch in addition to the normal 15 lb. The men can then open the door and enter the tunnel in which the pressure is maintained by the air pumps to 30 lb.

The object of maintaining such a high pressure is that it forces away any water or dampness from the soil, and the excavation is able to proceed as in normally dry ground, but the effect is much the same as would be that of living in a sodawater bottle, and, as may be imagined, it is not altogether agreeable.

Working in compressed air cannot be described as pleasant, especially in fairly high pressures, such as 27 to 30 lb. to the inch. At St Louis Bridge they used pressures up to 56 lb., and many deaths occurred.

One of my later experiences of similar work was in 1914 when I had to visit a tunnel under construction in one of the large cities in the north of England. When I arrived at the place, I found that neither the Corporation engineer, nor the contractor, nor even his representative, ever entered compressed air. Although I was far past such work, which ought to be limited to men under forty years of age, I had undertaken to inspect and report, and I therefore went in with the foreman. I saw all that was necessary, but I experienced much discomfort, and on coming out I realised that I had a very painful ear-ache. I returned to London, after attaining the object of my visit, thinking that it would pass off after a night's rest, but as the pain continued for some days, I consulted a leading aurist. He examined my left ear by electric light and reported that the drum of the ear was burst. I asked him to examine the right ear as well, and he found that this ear had also been similarly injured on some previous occasion, but had lightly healed over. He administered some remedies, and in course of time both drums healed up, so that I am only very slightly deaf. I had always understood that burst drums meant stone deafness. I am thankful to say that has not been my experience.

CHAPTER XX

TWO DANGEROUS EXPERIENCES

(1) A Visit to a Canal Tunnel

Many are the different kinds of tunnel which have been constructed at various dates in the world's history, from Hezekiah's conduit in Jerusalem to the Pool of Siloam, driven by hand labour underground, the tunnel under the Euphrates at Babylon in the days of Nebuchadnezzar, the water tunnel of Roman date in the Island of Samos, up to the great modern tunnels beneath rivers and mountains. The tunnel which I am about to describe does not belong to this last category; but it is, I think, unique of its kind, and the visit of inspection which I made to it was not devoid of personal risk.

The Act of Parliament authorising its construction is dated 1789–90. The tunnel was made at the end of the eighteenth century in order to carry a canal under rising ground, and also to enable water-borne coal, iron ore, and limestone to be delivered to some blast furnace. The works were connected by a vertical shaft to an underground quay known as the "Wide Hole" some 900 yards from the western portal of the tunnel. The total length is $1\frac{3}{4}$ miles or 3,080 yards, and its width is 9 ft., except at the "Wide

Hole," where the width is increased to allow barges to get past others lying at the quay.

The canal is the property of one of the main trunk lines of the kingdom. During the 130 odd years which have elapsed since it was constructed, thick seams of coal lying at a considerable depth below it have been and are still being worked, and it was desirable to know to what extent the canal was impassable. Therefore the tunnel has been let down to such an extent that the arch is submerged in places. Not only can traffic no longer pass through, but the brick walls and side arches have been crushed and destroyed.

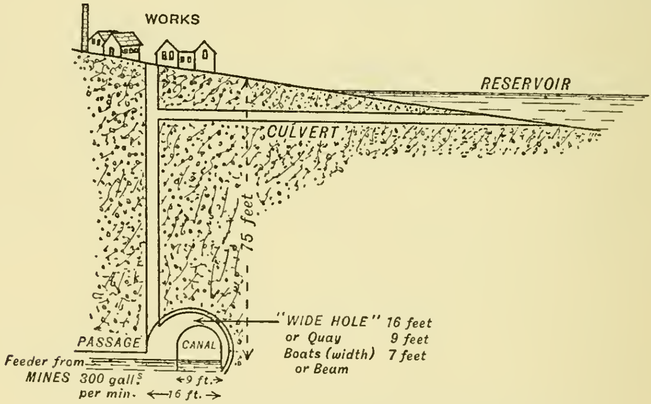

FIG. 25.—SECTION OF TUNNEL. "WIDE HOLE" AND QUAY.

Our visit took place on March 12, 1907. The last barge had passed through the tunnel about the year 1901. The barges are normally 7 ft. beam, but owing to the distortion of the tunnel it was found necessary to provide a chain and screw-coupling from gunwale to gunwale across the boat to make it still narrower than 7 ft.

Otherwise it would not have passed the contorted walls.

The railway company warned us that it was dangerous to enter the tunnel and that they would not be responsible if any accident happened to us. We afterwards heard that they had considerately placed a man at the top of each of the shafts, which had not fallen in, to see if we had passed, so that in case of an accident they could raise the alarm.

From the west entrance we went in 1,200 yards, the arch getting worse and worse, until eventually we found that the tunnel and the shafts had collapsed. From the east portal we were able to proceed for 800 yards, propelled by two men lying on their sides in the bow of the boat, back to back, and *walking* or "legging" on the side walls of the arch. At last we reached a point where the men asked us not to let the boat bump against the side walls for fear that they would fall in. Touching the roof of the tunnel gently with my stick I dislodged a small portion of the arch which fell into the boat. From this point for the remaining length of 1,080 yards both tunnel and shafts had caved in and we could go no farther.

It was with small reluctance, having fulfilled the object of our visit, that we returned to the open air, and exchanged a blue sunny sky for the roof of a collapsing tunnel. I confess that I shared the feelings of my host, when on returning he greeted me with the words, "I am relieved to see you again!"

(2) Explosion in Bermondsey (Christmas 1907–1908)

As I have touched upon the dangers of underground work, I will go on to describe an explosion in Bermondsey, which illustrates some of the many dangers to which our admirable borough engineers and surveyors are exposed in the course of their duties.

The explosion occurred some nine months after my visit to the wrecked Canal tunnel. I was rung up by the "Sister" at the Bermondsey Medical Mission about 9 p.m. to inquire if my daughter, Dr. Selina F. Fox, the head of that institution, were at home. "There has been a great explosion," she said, "and flames are rising from the street as high as the houses. What are we to do? The firemen have been in, and told us to put out our kitchen and other fires, and all gaslights and candles, and we are in pitch darkness, the electric light having failed." I decided not to disturb my daughter, who had returned from her work with a severe headache and had gone to bed, but asked Sister to ring us up in ten minutes. We sat over my study fire anxiously waiting for a message, but none came. At length, feeling sure that the telephones were destroyed, we telegraphed to Bermondsey. At 11 p.m. we were rung up again by Sister, who said: "I am speaking from another telephone, a quarter of a mile away, our own having been destroyed. The danger is over and we are going to bed but in the dark." I congratulated them on their escape, and as I could be of no service that night I arranged to go over the first thing in the morning.

When I arrived there next day I met Mr. R. J. Angel, the Borough Engineer, and with him made a personal examination underground. I found that there had been a heavy explosion. The surface of the street had lifted and had been broken for a third of a mile; doors and windows were smashed, iron covers from the manholes blown over the tops of the houses, two children were killed, a woman was injured, and many were suffering from shock.

What was the cause of the explosion? To explain this I must direct my readers' attention to the accompanying rough freehand sketch. The accident had happened in a street known as Grange Road, of which the sketch shows a section.

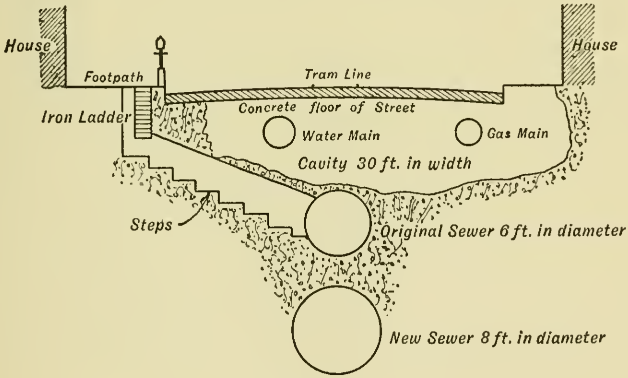

FIG. 26.

Many years ago a sewer, consisting of a circular tunnel 6 ft. in diameter, had been constructed beneath the surface of the street, and access was provided by a flight of stone steps leading down from the pavement. About the year 1888, the London County Council had, in connection with their general system of London drainage, constructed a new sewer 8 ft. in diameter at a lower level, the former one being abandoned. In order to save expense this old sewer and the steps leading to it had never been filled in, and this desire to economise was ultimately the cause of the serious accident.

The single line of tramways which traverses the street is carried on a concrete foundation, the entire width of the street; and beneath this concrete floor ran gas main, water main, telegraph and telephone wires, electric light main, besides many small drains and drain-pipes.

At some time—probably months—previously, a leak had occurred in the water main, but no ill-effects of any magnitude would have resulted, had it not been for the close proximity of the stone staircase. The water gained access to this, and washed the subsoil away from under the street into the old sewer. A large cavity 30 ft. wide, 20 to 30 ft. long, and 6 ft. deep was thus produced, and the soil which gave support to the gas main was thus taken away. This main "sagged" or sank several feet, the joints were broken, and an explosive mixture of gas and air filled not only this cavity, but also the staircase, and the old sewer for its entire length of about 600 yards. A strong smell of gas was noticed in the street, but no one knew whence it came. Meanwhile the electric light cable and the telephone and telegraph wires were also deprived of their support, and this resulted in a regular, or rather an irregular, "mix-up" of everything. How the explosive mixture was ignited was never finally explained. But it is thought that there was an escape of gas into the parlour of a public-house where a number of men were quietly sitting round a fire talking; there it was ignited either by a light or by the fire; the resulting explosion blew the fireplace into the room amongst the men; and the flame travelled down the staircase to the old sewer which exploded and wrecked the street.

Another suggested explanation is, that at the east end of the street some men were repairing the electric cables with the aid of a powerful naked flame, and that this ignited the gas.

Grange Road was completely blocked to traffic and the Borough Council requested me to report on the accident and its cause. It certainly was one of the many very dangerous things I have had to do. In company with Mr. R. J. Angel, the able Borough Engineer, I descended the stairs, which were cracked and bulged. Blocks of concrete, each a ton in weight, had been detached and blown along the old sewer like heavy shot in a huge gun-barrel; the arch itself was wrecked, and liable at any moment to collapse. We walked and crawled along the brickwork, which was shattered, and when I gently touched the arch with my stick some of it fell on my hat. We were thankful when we reached the surface uninjured.

At first sight the Gas Company seemed responsible; but they claimed very fairly that if their main had not been deprived of its support no gas would have escaped. The County Council said that the accident was due to the escape of gas and that the Water Company were liable in the first instance because their main leaked. The Borough Council claimed that the disaster was due to the L.C.C. having left the old sewer empty instead of filling it up; for if it had been filled, the earth could not have been excavated and carried away by the water.

After six months' delay during which no traffic passed along the street, and after threatened legal proceedings, the London County Council admitted their liability for not having filled up the old sewer.

The street had to be opened up from the top, the old sewer filled in and the roadway repaved. Now all that remains to remind the public of the accident, are the graves in the cemetery of the two poor children who were killed.

CHAPTER XXI

ON WORKMEN

(1) Accident Averted at "The Shipperies," Liverpool

I WAS fortunately an eye-witness of a very brave act on the part of some of the well-known "riggers" of Liverpool during an unusually heavy gale in March 1886.

The building of the Antwerp Exhibition had been purchased by the Liverpool Corporation for the purposes of a sea-faring and nautical Exhibition. The structure, which came to be known as "The Shipperies," was being erected on fairly high ground at Edge Hill, and I had been consulted by the Corporation, Sir David Radcliffe being Lord Mayor, upon certain details of the construction which were unsatisfactory in the Belgian building. I visited the site in company with our assistant engineer in Liverpool—Mr. Archibald H. Irvine—and we decided that extensive cross bracing was necessary, or part of the structure would possibly collapse. I had arranged to return to London next morning, but during the night a heavy gale sprang up, and I decided to remain until the afternoon to see how the ironwork withstood it.

Irvine and I entered at a side door and saw two large gangs of men hauling at some ropes, which were fastened to portions of the ironwork at a great height above our heads. The roof was out of the upright, and there was therefore more or less danger. Suddenly there came a tremendous gust of wind; and large sheets of glass and zinc came crashing down all around us, the glass "dagging" cornerwise into the timber flooring. We ascertained later from Mr. Hartness, the astronomer at the Bidston Observatory, that the gale had reached a velocity of 60 miles an hour, with a pressure per square foot of between 30 and 40 lb. I suggested to my companion that we should be safer outside. Just as we were leaving, we saw a portion of the building which covered about an acre of space bend sideways, fall, and lie almost level with the ground. Fifty men were working in this portion, but the previous gust of wind had induced forty-eight of them to run outside: of the remaining men, one was killed and the other injured.

Immediately a panic seized the workmen in the main building, and shouting loudly to their mates, they came down from the roof, sliding down ladders, poles, and ropes until there was not a man left in the place. They collected, some 1,500 in number, on a rising mound far enough from the structure to be out of harm's way, expecting the remaining acres of building to collapse. Fortunately this did not happen; but three or four columns, each 80 or 90 ft. high, from which the fallen ironwork had been torn, were swaying about in the gale, ready to fall.

Some of the riggers saw the danger, and without a moment's hesitation ran into the building, seized some coils of rope, and with these round their necks swarmed up the columns. When they reached the very top, they sat down, attached the ropes, and threw the coils to the men below. Stakes were hurriedly driven into the ground, and the ropes were fastened as guys, and by these means the swaying was stopped and the threatened fall of the columns prevented. The men then returned to their comrades on the mound as if they had done nothing unusual, and awaited results. Their courage and indifference to danger undoubtedly saved the rest of the building.

(2) Subsidence of a Tunnel Prevented

To the remarkable courage on the part of working-men which I have just related, I will add an instance of watchfulness and care by the plate-layers in a certain tunnel, which prevented its subsidence and the expenditure of a great deal of money.

As the men were making their regular examination of the permanent-way in the gloom and smoke of the tunnel, the foreman noticed a small round piece of some white material, about the size of a shilling, lying on the ballast. He thought it was a fragment of a torn-up letter, but examining it with his lamp he found that it was pure white on one side, jet black on the other, and about the thickness of a postcard.

He climbed up to the arch over the spot where it was lying, and found a corresponding white mark in the sooty deposit on the tunnel roof.

It had been broken off by some movement, and, although blackened with soot from the engines on the exposed side, it brought away some of the original whitewash of the arch. He at once sent for the local engineer; with the aid of ladders they examined the tunnel, and measured its width and its height, and were alarmed to find that the former was 12 in. narrower than it was originally, and the roof nearly the same measurement lower.

On closer examination a large crack was discovered from A to A and from B to B. This reduced the bearing area of the tunnel walls at A and B to one half, with the result that the arch of the tunnel was being forced by the superincumbent weight into the clay. Unless immediate steps were taken to stop this process of subsidence, it was evident that the carriages would not be able to pass through.

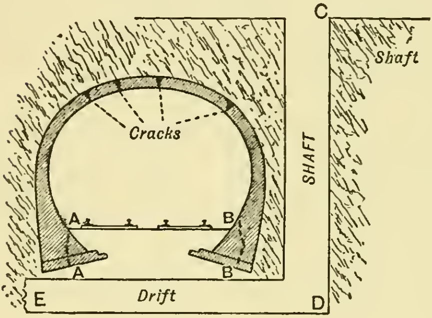

Fig. 27.

The traffic amounted to about a thousand trains a day, so that no repairs could be undertaken whilst they were running. We therefore adopted the following method. Strong baulks of timber were fixed under the permanent-way from the side wall at A, to the side wall at B, so as to prevent further movement. Shafts were then sunk from the surface at C down to D;

and under the walls and railway from D to E were driven galleries or driftways, which were filled and packed tight with concrete and brick-work. By these means the bearing area of the foundations was greatly increased. The arch itself was cracked and open in many places, but this was easily rectified. The length of tunnel which had failed was about a quarter of a mile. It was a great relief when the work was finished, especially as the tunnel was rendered better and stronger than ever before.

The origin of the word "platelayer" is not without interest. Amongst the wounded whom we used to entertain in the recent war, several were platelayers, but not one could give the reason for the name. The invariable answer was "because we lay rails," until I pointed out that "rails" were not "plates."

The sketch on p. 240 shows the earliest form of rail employed by Trevithick in 1803. At that date coal was sent from the South Wales coalpits to the port for shipment in the old "chaldron" wagons. The same mode of transport was used in Northumberland and Durham. These chaldron wagons ran on the ordinary roads without rails, which at that date had not been invented, and the result was that deep ruts were formed in the roads. To prevent the ruts it was suggested that cast-iron plates should be laid on the surface of the road between A and B. The men who laid these plates were naturally enough called "platelayers."

It was soon discovered that the horses which hauled the trucks could not get foothold on iron plates, and Trevithick, about the year 1803, conceived the idea of turning up the edges of the plates so that the wheels were prevented from meandering all over the road, and were practically kept in gauge. The amount of the plating was thus largely reduced. In course of time the flange was transferred from the plate to the wheel itself, and by degrees the head of the rail was increased until it assumed the form which is now in use on every railway in the world. But the term "platelayer" still remains, to remind us of ancient history.

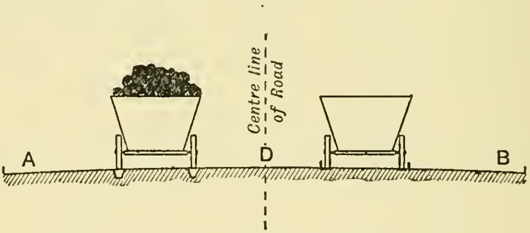

Fig. 28.

Chaldron Wagon loaded with coal for shipment; the road cut into ruts and was covered with cast-iron plates ADB.

The edges of the plates turned up, thus rendering all other plates unnecessary, except immediately under the wheels.

(3) Treatment of Workmen on the Great Central Railway

When I was instructed in 1894 to take in hand the extension of the Great Central Railway between Rugby and London, the first thing that I attempted to do was to win the goodwill and cooperation of the landowners and residents on the route. Starting at Rugby, I engaged a carriage and a pair of horses (motors hadn't yet come into general use) and drove through the entire district of the projected line. My first visit was to Rugby school, where I called upon the head-master, Dr. Percival, afterwards Bishop of Hereford. I explained that work on the railway was about to begin, and would bring some 10,000 men into the district. I said that the Company and the contractors would do their best for the comfort and welfare of the men, their wives and children, that they wished to prohibit the sale of strong drink, and that they fully appreciated the need for protecting the landowners and residents from the inevitable but very small percentage of evil-disposed persons. For all these reasons comfortable houses or suitable huts must be found, schools and recreation rooms erected, and co-operative stores established. Above all, the goodwill and kindness of the residents must be secured. Dr. Percival thanked me for coming to see him before work was started, and promised that he would at once lay the matter before his friends.

Continuing my journey, I called on the various clergy, Free Church ministers, landowners, and tradespeople—with very useful results. The Archbishop of Canterbury requested the Bishop of Peterborough to take the strip of line into his Diocese during the period of construction. The Diocese therefore temporarily included the strip occupied by the railway from Rugby to a point forty miles south; when coloured on a map, it looked like the trunk of an elephant extending far beyond the boundaries of the actual Diocese.

A local committee formed in the district undertook to provide Scripture readers and visitors, and spent a good deal of money on social work amongst the men.

The contractors, Messrs. Scott & Middleton and Messrs. Oliver & Sons, took great interest in the men and their families. Our excellent inspector and his wife Mr. and Mrs. Glen gave us their invaluable assistance. In return for all this effort the employees, all along the line, responded most loyally. There was very little crime and pilfering, and remarkably little poaching. In fact, when the men finally left the district there was a general feeling of regret.

In all contracts for engineering works, Sir Douglas Fox and I always inserted a clause prohibiting Sunday work if it could in any way be avoided. We held that everyone required a rest on one day in seven ; and we believed this to be the reason for a Divine institution. In obedience to that most beneficent command for the welfare of mankind, we have done our utmost to secure for all their day of rest, and we have always found it conducive to health and kindly feeling.

On the Great Central Railway a tunnel, two miles in length, through slippery clay, had to be built in the shortest time possible. There were ten shafts, and at each shaft two "faces" or ends, besides the two portals. Thus there were altogether twenty-two places at which work was proceeding. Hoping to accelerate progress, the contractor came to me, and urged me to strike out the clause prohibiting Sunday work. I replied that it was useless to ask me to do that since we were convinced from long experience that it would delay completion rather than hasten it. He went away disappointed. The work went on as before, the tunnel was opened for traffic, and nothing more was said on the subject.

Three years later he called upon me and reminded me of his request and my refusal. And then in a frank and open manner he went on to say: "We have just completed another tunnel in the north of England in which Sunday work was not only allowed, but was compulsory, being ordered by the Company, and we found that both loss of time and unnecessary expense were incurred. The men came back to work worn out on Monday instead of being refreshed by a Sunday's rest: the men, the boys, the horses, the very engines and boilers need this cessation from work. The avoidance of Sunday work on your tunnel saved considerable time, and the work was completed in a record short period."

> "A Sabbath well spent, brings a week of content
> And strength for the toils of to-morrow;
> But a Sabbath profaned, whate'er may be gained,
> Is a certain forerunner of sorrow."
>
> SIR MATTHEW HALE.

(4) MR. AND MRS. WILLIAM GLEN

In June 1866 I had to visit Edinburgh on business—the first time I had ever been in that fine city. I arrived by night mail from London at 6 o'clock on Sunday morning. At 11 I went to the first church I saw, and found it to be a Scottish service, the congregation sitting down to sing, standing up to pray, followed by a theological sermon. It was my first experience of a Scottish service and I enjoyed it enough to repeat it in the evening. After the evening service I was wending my way towards my hotel, past John Knox's house in the old High Street, where the streets were very dimly lighted, when I came across a crowd of several hundred people listening attentively to an open-air preacher. I stopped and heard one of the most impressive Gospel addresses I had ever attended, and this was my first introduction to dear old Glen.

When the service was over a hymn was splendidly sung by the massed people, and then in the gloom of night the crowd quietly dispersed.

The preacher turned down a dark street and walked away by himself. I followed and endeavoured to enter into conversation with him, but he was very reserved and would say little. However, when he found I was in earnest, he asked me to come into his lodging in Bristow Street, in one of those tall tenement houses of old Edinburgh. After taking me up several flights of a winding stone staircase, he unlocked a door opening into a pitch-dark room, and lighted a candle. It was a single room, barely furnished, and he was living alone, as at that time he was unmarried.

I found that he was a stonemason earning £1 a week, who, with two or three other masons, was conducting a night school in order to keep the young men and women out of the streets. I said that I should like to assist him. He refused my offer at first, but at last he said that sometimes the rent of the room, £6 a year, was difficult for them to pay: and if he might write occasionally for a little assistance towards this he would be glad. I agreed, and for a couple of years or more sent him a cheque now and again.

Then I wondered if I was doing right in continuing this, and I wrote to the English Episcopal Clergyman in Edinburgh (whom I did not know) to ask if he could find out anything about Glen for me. An answer came back promptly to the following effect: "William Glen? Yes, indeed, we all know him; a splendid fellow, doing Christ's work. Anything you can do to assist him and his co-workers will be all right."

So I continued to send my contributions. Then for a time he was silent, I had no reply to my letters and feared I had lost touch with him. At last a letter, evidently written with difficulty, came in which he told me that he had had an accident. He had fallen from the roof of a house and had been picked up for dead. He lay for a long time in the hospital, and when at last he was able to get about he set himself to visit the patients; and he added, "If only I could ensure the same results I am willing to have the accident over again."

In 1872 I was manager of an important mine in Yorkshire in the Cleveland district[1] and I needed a man to visit our miners and their families. I offered Glen the post of mason; he was to look after the houses and buildings and to devote his afternoons to visiting. The need was great,

[1] See Chapter XVIII, p. 210.

owing to the extraordinary development of the mining district. The parish was a very large one, of some 2,000 to 3,000 acres, with a sparsely scattered population of only 160 people and no railway. The Vicar was a dear old man, nearly seventy years of age, and quite unaccustomed to the rush and turmoil of a mining centre. Suddenly the railway came, mines were opened, and before we knew where we were, the population had increased to 4,000 or 5,000; our own village alone contained over 1,000.

We built a fine schoolroom, which was licensed for church services; but as the miners were, almost without exception, Cornishmen, and Wesleyans, a Wesleyan chapel or church was built for their accommodation. The Episcopal Church congregation was very small.

The Vicar endeavoured to the best of his ability to visit the families, but it was an impossible task. I therefore instructed Glen to do his best to get them to some place of worship—if not to church, then to the Wesleyan chapel. The Vicar—I am sorry to say—did not approve of the arrangement. Indeed relations between us were strained. He charged me with having "introduced a poacher into his parish who endeavoured to undermine his authority," and it was useless for me to try to convince him he was mistaken.

Glen soon won the friendship of all the men and their wives and children, and his efforts were well assisted by Mrs. Glen, a dear motherly woman. They were regarded as the "father and mother of the mine." If an accident happened the first cry was " send for Glen " ; and very soon he and his wife were on the spot doing all that lay in their power. They were welcomed into every house —except one, and that was the Vicarage.

In course of time the old Vicar fell ill, and to everybody's surprise Glen received an invitation to go to the Vicarage, into which he had never previously been admitted. He went, and found the Vicar lying on what was soon to be his death-bed. The Vicar received him very kindly, shook hands with him and said : " Mr. Glen, I have only a short time to live, but I want to tell you how sorry I am that all these years I have misunderstood you. I thought you were working against me, using influence with the men adverse to my position, but I find I am mistaken. It is too late for me to make reparation, but as I wish the parish to be aware of the facts I shall be grateful if you will be one of my bearers to the grave." Truly the act of a Christian gentleman.

Soon after this there was a great falling off in the iron trade. About one third of the Middlesbrough district migrated, and a large number of ironworks, blast furnaces, and mines had to be closed. Pig iron, which in those days was considered abnormally high at 120s. per ton, fell to 27s., and many people were ruined.

I appointed Glen to other work, and he acted for us as inspector during the construction of many large works. He was engaged on the Mersey Tunnel, the Liverpool Overhead Railway, the Scarborough and Whitby Railway, the Hawarden Bridge over the River Dee (the largest opening span in England), where one of his sons was accidentally killed, the Great Central Railway, the Great Northern and City Railway, the saving of Winchester Cathedral, of Corhampton Church, of the walls and towers of Chester, and many other undertakings. Wherever he went, not only did he carry out his duties as an inspector perfectly, but he gave all his spare time to the work which lay nearest to his heart; and being an excellent preacher and a profound Bible student, he was frequently asked by various Free Church bodies to occupy their pulpits.

Both Glen and I recollected our first meeting in Edinburgh, June 1866, for years afterwards, and the text and the sermon have never faded from my memory: "He was wounded for our transgressions, He was bruised for our iniquities . . . and with His stripes we are healed" (Isa. liii. 5). "The mere belief that Christ came into the world or that He died won't save us: but what will is, His *substitution* for us."

William Glen died on November 4, 1912, at the age of seventy-four, having been in our service continuously since 1872. His widow, Mrs. Isabella Glen, followed him on January 22, 1921, at the age of eighty-eight. Like her husband, she had written to me a delightful and grateful letter only a few days before her death. They were both buried at Brackley, Northamptonshire, and I counted it a privilege to be present on these two occasions. For Glen and his wife were of the salt of the earth; and they were among my most valued friends for over fifty-five years.

CHAPTER XXII

SOCIAL WORK IN LONDON

My brother and I used to occupy our spare time in visiting the poor districts of London and getting to know the residents. We came in this way to witness many sad and pathetic, and sometimes amusing, incidents. There is still great poverty in London; but it is not so bad as it used to be. I am happy to think that at the present time much more attention is being directed to the grave necessity of better houses for the people.

In 1861 in the purlieus off Drury Lane I was visiting a terrace of well-built early Jacobean houses—once no doubt an aristocratic quarter. The houses had handsome front doors and substantial iron railings with torch extinguishers. They have long since been demolished. I had been directed to a particular house by a child in the street leading a blind and lame man who sold matches. A few days later, wishing to meet the old man and his guide, I mounted to the "second floor back" and knocked at the door. It was opened by a woman who told me that in every room lived one or two families and that the man and child of whom I was in quest could only be reached by going through her room to a smaller one at the back. This proved to be an old "powder closet," just large enough to take in the old man's bed ; the girl slept on a mattress on the floor. Soon after my visit the old man died of consumption.

Rumour, probably exaggerated, stated that in one of the large rooms in that street a separate family lived in each corner, divided off from each other by ropes and curtains. Matters went on fairly smoothly until one of the families began to take in lodgers. This was too much for the others !

In 1865 we lived at Blackheath, and occasionally attended the ministrations of the Rev. Dr. Miller, the Vicar of Greenwich, and also of the Rev. Adolph Saphir, D.D., of the Scottish Presbyterian Church in the same parish. The latter was a very able preacher with a marvellous knowledge of both the Old and New Testaments. He was a converted Jew, and had studied the Bible closely in the original Hebrew and Greek.

A lady visitor working under Dr. Miller, amidst the severe poverty which then existed, had an extraordinary experience. She was requested to go to a certain house where a woman was in distress, and on arriving there at a time she had fixed, she heard that the woman's daughter, a child eight years old, had died. The mother appeared to be destitute. She took the lady upstairs and showed her the body of the little girl lying covered by a white sheet. The visitor was much distressed. She emptied her purse into the mother's hand, and promised to go home at once and send her some supplies. On reaching the street, the lady found she had left a glove in the bedroom and went back to get it. The mother was in the child's room and the visitor hesitated to intrude upon her grief. However, she gently opened the door—to discover the child sitting up in bed and asking her mother, " Shall I play dead any longer ? "

About 1880 I was asked by a friend who had just left Cambridge if I could enable him to see something of the deep poverty of London, which was only known to him from written descriptions.

The best way to do this was to ask the London City Missionary, Mr. Baxter, with whom I had worked for some years, to take us round. This excellent body of men knew more of London than even the police. In the eighties there were streets through which it was not prudent for a constable to pass. Mr. Baxter suggested that we should first visit a thieves' kitchen in Deptford, which was known by the fraternity as one of the " underground stations " in the criminal life of London. A thief could lie hidden there during the day ; at night he would be passed on to the next " station " in order to baffle the police. The lodgers paid 4*d*. a night, which entitled them to a rough bed, and the use of the large coke fire in the basement. They cooked their own food, and had numerous herrings, rashers of bacon, sausages hanging by hooks on to the bars. Mr. Baxter held a simple service for these men every Sunday afternoon, and it was interesting to notice the code of etiquette which existed among them. Once a year we had a special service, and an excellent tea for the lodgers, an event to which they looked forward for months in advance.

The next house we visited was in a street which had been once a fashionable part of London in the days of Evelyn and Pepys, but now consisted of single-room tenements each accommodating one family. On the third floor the missionary knocked at the door, which could only be opened six inches —children were lying on the floor, covered with dirty blankets. This conversation followed:

"Mrs. Jones—you are late this morning."

"Yes, sir, I am—but as I was without food for the children, I found the best way to keep them quiet was to make them stay in bed."

At a third house we entered a room almost bare of furniture, which was occupied by a young man and his sister. Their only cooking utensils were an old kettle and a jampot, in which they were making some cocoa. For fuel they were pulling up the boards of the floor.

When we had returned to the street, my friend emptied his purse into the missionary's hand and said: "I've had enough of this! Can I do anything to help you in your work?" Mr. Baxter replied that the chief need was for clothing and work. No sooner did my friend reach his house near Hyde Park than he packed part of the contents of his wardrobe into a trunk and sent it off. But a difficulty, which he had not foreseen, presented itself. They were such excellent clothes that they would have been at once pawned by the person for whom they were intended. So I asked my friend if the missionary might retain them for his own use and distribute his own worn and shabby garments. The request was, of course, granted.

But the solution was not an ideal one for all parties. Mr. Baxter was 6 ft. 1½ in. in height, whereas my friend was only 5 ft. 9 in. For the next two or three years the missionary's sleeves and trousers were several inches too short !

Some years ago we were visiting the slums which then existed in Westminster. A law had recently been passed providing that children in arms might not be taken into public-houses. One day when I was passing through this neighbourhood, I noticed two ragged women with unkempt hair sitting on their heels outside a public-house. A tidily dressed woman came up carrying an equally tidy baby. She evidently knew these women and asked them to hold the child whilst she went in for a drink. They were only too pleased at this request, and as I passed by I heard one say to the other "Oh ! ain't we highly flavoured." I learned afterwards that this was quite a common expression.

Another important branch of social work is that of my eldest daughter, Selina Fitzherbert Fox, M.D., B.S., which she instituted twenty years ago in Bermondsey, one of the poorest parishes in London, entirely on her own initiative. It is known as the "Bermondsey Hospital and Medical Mission," and during this period over 500,000 poor women and children have passed through her hands. She has a fine staff of lady doctors, surgeons, and oculists who are able to deal with the most severe operations : the result is they are beloved by all, and the industrial classes voluntarily raise some of the necessary funds.

CHAPTER XXIII

WAR WORK (1914–18)

In a book of recollections, such as these, extending over the last sixty-three years, it is impossible to avoid some account of the years of war from 1914 to 1918.

At the outbreak of war I had to attend as a magistrate at the recruiting office in Wimbledon to assist in the swearing in of the endless queue of men who responded to their country's call, my only remaining son and partner, F. Harry W. Fox, being one of these. He having been trained as a mechanical engineer had been offered a commission in the Royal Engineers, but preferred to go through the ranks as a private. It happened to be his birthday, September 24, 1914, when he came up to be attested, and, being a fully qualified motor-car and lorry driver, he entered the Royal Army Service Corps. After training at various camps he was promoted corporal, then sergeant.

From Avonmouth he went to Egypt and was encamped near the sea at Ramleh. Thence he transferred to the Royal Engineers 13th Field Company, 29th Division, and served at Gallipoli, Suvla Bay, Cape Helles, and had his fill of the horrors of the engagements there. Towards the end of the Gallipoli campaign he was sent to hospital in the Island of Mudros, where he remained for five weeks, before being sent home in the hospital ship *Aquitania* to recuperate. When he was again fit for duty he went to France as an officer in the Royal Engineers, and in due course attained his captaincy. He was in the Ypres sector for 2½ years, like millions of others was exposed to all the incidents of war, often under heavy fire and aeroplane attacks, especially at Vimy Ridge in which he lost many of his best men.

Soon after the Armistice he was sent out to South Russia with the rank of major, to assist General Denikin. He landed at Novorossisk, which became his headquarters, and in the course of his duties visited the Crimea, seeing Kislovosk, Yalta, Balaklava, Odessa, Taganrog, Rostock, and the coal mines of the Don Valley, where he reported on the condition of the underground and mechanical work ; he also went to Ekaterinodar. On returning to Novorossisk, where he was erecting a large number of heavy locomotives from America, he had the gruesome task of unloading five miles of carriages and horse boxes filled with soldiers and refugees flying from the Bolsheviks. It was no uncommon event to find all the occupants of a horse box or carriage suffering from typhus fever or frozen to death.

My own part in the War was less exacting and exciting than this, but I seem to myself to have learned from it something worth setting down on paper.

When Lord Kitchener called for a hospital accommodation of 50,000 beds, the country was appalled at the demand. But before Peace was declared 500,000 had to be provided. When the terrible cases of wounded and maimed began to arrive in 1915, the new Stationery Office near Waterloo Station was transformed into a great hospital known as King George Hospital. The building contained 2,000 beds, every one of which was soon occupied, and everything possible was devised for the comfort and well-being of the sufferers. Ambulances met the hospital trains at the station, and almost before the mud of Flanders trenches could be removed, the men found themselves in comfortable cots with gentle and loving hands ready to do anything and everything that was required. There was a large and excellent staff under a very humane and sympathetic commandant. Any time I could seize from my office was spent in visiting this hospital; the wards I knew best were those devoted to facial injuries. These sad cases required even more sympathy and care than the others. Gifts of grapes, peaches, nectarines, plums, tomatoes, and the like, were most thankfully received, for to many of the patients mastication was impossible. At times some wounded man would set such a fine Christian example to his ward that the moral change brought about in his fellow-sufferers became quite noticeable. From such men the visitor, as well as the patients, drew the encouragement so sorely needed.

Lectures, entertainments, and gatherings were arranged and a lecture hall, in addition to a chapel, was fitted up. Most of these entertainments were of great interest to the sick and wounded, but some were hardly suitable for men who had passed through such terrible and searing experiences. As an experiment I started a series of lectures and demonstrations on Science. These proved a great attraction to the men, and became an established institution. I was sitting one day at the bedside of a badly wounded man and remarked to him that there was plenty of amusement provided. "Yes," he said, "I get the orderlies to wheel my cot to the Lecture Hall, but, after one or two comic songs, I have had enough, and ask them to wheel me back to the ward, but when you lecture I 'stick' it!"

I printed a small pamphlet, called *Talks with our Wounded Heroes*, describing the right method—as it seemed to me—of occupying and distracting the minds of the men. Some thousands of copies were given to the wounded as a slight record of what was explained to them during their time in hospital, or in our house. Besides the King George Hospital, we visited the Wimbledon Hospitals, the large Kingston Hospital at Malden, and the No. 3 London General Hospital for 2,000 officers at Wandsworth. From these institutions we entertained at "Alyn Bank" between 2,000 and 3,000 wounded, besides officers and troops from Wimbledon Camp—a privilege which could not but leave a lasting impression upon the minds of all who came in touch with men of such courage, patience, and cheeriness. It was at "Alyn Bank" that I mainly carried out the programme of scientific talks and experiments described in my pamphlet, extracts from which follow:

The question of light is one of the most attractive. If the electric light is available (or, failing that, a gaslight, or oil lamp, or even a candle will suffice) it is asked, " Where does this light come from ? " In the case of the electric light, from the generating station, where it is produced by dynamos ; these in their turn get their power from boilers, under which coal is burnt. But where does the coal obtain light ? From the forests, which were growing during the Geological period of the carboniferous series, which forests absorbed the heat and light of the sun (the same sun which blazes in the sky to-day) millions of years ago. But where does the sun obtain these ? And now science which tells us all these facts is at the end of its tether ; it is brought up with a round turn and cannot go farther back. It is baffled and puzzled, and although it may tell us of vibrations and undulations, with the theories of Helmholtz and other philosophers, it has to admit that it is beaten.

What has to be done ? Only one source of further information is available, and that is God's Book—the Bible—and every true scientist will readily accept its assistance.

In Gen. i. 3 we are told " God said, Let there be light, and there was light." No further information is vouchsafed until Gen. i. 16, when the sun and moon are created probably æons of geological time later. So that we see light preceded all these orbs, which are secondary agents for the distribution, not the creation, of light.

We read that Moses at Sinai having seen God face to face had to cover his face with a veil because the ineffable light which he had received was too bright for other men to see (Exod. xxxiv. 29-34).

Then we go on to the Psalms, and we find in Psalm lxxiv. 16, that David evidently knew more about light than we do, for he says, "Thou hast prepared the light and the sun," not "the light of the sun," thus showing that light and sun are two distinct entities.

In the account of the Transfiguration of Christ, Matt. xvii. 2, we read, "His face did shine as the sun, and His raiment was white as the light;" and when Paul was on his way to Damascus, Acts xxvi. 13, he says "at midday," that is just when the sun would be at its brightest, "O King, I saw in the way a light from Heaven, above the 'brightness of the sun.'"

In 1 John i. 5 there is the distinct statement, "God is light." Thus we find that throughout both New and Old Testaments, from the very commencement, light is constantly referred to; but we must now go to the last chapter of Revelation, xxii. 5, and there the whole mystery is disclosed, for in the description of the heavenly Jerusalem we read "they need no candle, neither light of the sun." Why? "for the Lord God giveth them light." From all this it would appear that light is an emanation from the Deity Himself, and this accounts for its exquisite beauty. Every colour in the spectrum comes from light, every flower, every petal, every cloud, every wave or mountain or landscape owes its loveliness to light.

Another very interesting subject for consideration is, that a ray of light from the sun is divided by a prism into three primary colours—violet, yellow (or green), and red, and these can be again reunited to form white light, so that this natural phenomenon shows not only the possibility but the existence of One in Three and Three in One, the most perfect illustration in nature of the doctrine of the Trinity. This can be followed still further, for *violet* is the chemical and actinic ray, *yellow* is the lighting ray; *red* is the heating ray;

and these correspond more or less closely to the functions of the three Persons of the Trinity.

A remarkable fact in connection with the sun is, that even on the coldest day of winter, if it be shining, sufficient heat falls on every square yard of the surface of the ground to melt iron.

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The formation of rain drops is easily described by suspending two balls of pith (the size of vegetable peas) by two silk threads about an inch apart. With the aid of a vulcanite ruler or celluloid knitting needle and a silk handkerchief these balls can be electrified by static or frictional electricity, with the result that as each ball is charged with the same sign of electricity, they repel each other, and hang three or four inches apart and one will not have anything to do with the other.

Upon this apparently simple law great results depend, for without it rain drops would come down in huge masses, probably as large as houses, destroying everything in their path.

Rain results from fine globules of water suspended in the sky, but so minute that the action of gravity is overcome by any upward current of air ; these globules coalesce and gradually attain the size of a drop of rain which then begins to fall. In falling, static electricity is produced by the friction between the air and the drop, so that each drop repels its neighbour ; travelling side by side for probably a mile they will, like the pith balls, have nothing to do with one another, each carrying with it its quota of electricity which it discharges into the ground. This explains the phenomenon that after rain, however heavy, the soil is beautifully light and friable instead of being worked into mud as is the case when we use a hose or a water-can.

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Sir William Crookes' exhausted tubes are more difficult to exhibit, requiring as they do an electric coil and accumulator, but they are some of the most lovely and interesting objects for a gathering of wounded men.

In one tube there are five very unattractive-looking minerals very much like pieces of chalk or limestone, until the electric current is passed through them in a darkened room; they then become radiant with the most lovely and diverse colours, intense greens, reds and lilacs.

In another tube is fixed an ordinary whelk-shell such as is found on the beach or on the fish-monger's slab. Nothing pretty or attractive in its dull drab colour, except its form; but the current being switched on, it becomes an exquisitely beautiful object. Part of it has an intense blue which is best compared with the tint of the rising sun on some mountain, with occasional patches of brilliant gold; the mouth of the shell can only be likened to a fairy cave lighted up with perfect loveliness.

These objects can be used for illustrating the effect produced on the character of a vicious and repulsive human being; when the Spirit of God takes possession of his heart he becomes at once transformed into an entirely different personality, and instead of being repellent is attractive and lovable.

Professor C. V. Boys, F.R.S., wrote a small book, published by the S.P.C.K., on *Bubbles and Bubble-blowing*, which gives complete instructions as to how they can be produced.

It is unnecessary to describe their loveliness, but the great size which can be attained, some being 12, 15, or even 18 inches in diameter, and the possibility of blowing one bubble inside another, and also to pass a bubble round the room from person to person, render their exhibition a source of great interest.

Chladni's sand figures on a brass plate, produced by vibration, are very entertaining to the men, especially if they all are invited to try their skill in working them.

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All soldiers know only too well what the word *Explosion* means, but few know *Implosion.* This can be shown by putting a small quantity of water into a tin can and boiling the water until the can is filled with steam. It is then corked up and cold water quickly thrown over it. The steam is immediately condensed, a vacuum being formed, with the result that the can is crushed in by the pressure of the external air. This explains what happens when a steamer founders at sea and it is reported that the boilers exploded, the fact being they imploded.

Another branch of work was the Canteen under the arch connecting the platforms at Waterloo Station. This was started by that devoted and capable lady Mrs. S. B. Wilson, C.B.E., and her able staff of 160 voluntary lady workers, of whom my daughter Mrs. Walter Weston was a very active member. They used to meet the incoming ambulance trains and supply food to the wounded in their cots on arrival. They also entertained the troops leaving for the Front, and those returning on leave. In addition they provided for shipwrecked and torpedoed sailors and soldiers, for repatriated and starved prisoners, and for released Russian and German prisoners. The Canteen was in a most cramped and unsuitable place under an arch between the platforms and was entirely devoid of daylight. A bronze tablet has been fixed in the wall of the passage stating that "at this spot eight millions of men were received, fed, and cared for."

During the War one of the lady superintendents of the Wimbledon Branch of the Red Cross Society appealed to me to obtain for her linen and calico, of which there was great need, and scarcity. I explained to her that I was not a linen-draper, but promised to think the matter over and see what could be done. It occurred to me that, as civil engineers, we had many drawings and maps mounted on fabrics of various kinds, such as nainsook, butter muslin, brown holland, linen, and the like, and that when these drawings had served their purpose there was no further use for them. I had, for instance, some long sections of the Cape to Cairo Railway varying in length from 30 to 70 ft., which were not wanted owing to the Railway, during construction, having been slightly diverted. I had these sent down to my house and soaked in the pond. The drawing paper could then be stripped from the material on which it was mounted, and the latter was sent to the laundry to be washed and sterilised. The paper, of excellent quality, could be used for other purposes. The result was most satisfactory, more especially as the calico or linen was made long before the War, and was of a much finer quality than anything the shops could supply. The linen was, indeed, often of the finest quality, and as good as new; such was that from the drawings of the London and Birmingham Railway —seventy years old.

My wife and a lady friend took the work regularly in hand. We soon had drawings floating in two tanks which we established for the purpose, some bearing the signatures of such eminent men as Robert Stephenson, Sir John Fowler, W. H. Barlow, of the Midland Railway Company, Sir Charles Fox, and many others. The material proved of the greatest value for hospital purposes and saved the institutions to which it was supplied from a large expenditure. We had many most grateful acknowledgments. The purposes to which it was applied were bandages, splints, slings, substitute for cotton-wool, sheets for operating-tables, gowns for the surgeons, pocket-handkerchiefs, vests, pillow-cases for the wounded in Palestine and Mesopotamia.

An appeal, inserted in the daily papers under the heading " New Linen from Old Plans," drew very large consignments of old drawings from a number of engineering firms, railways, Government Offices, and various other establishments.

Designs delineated on the drawings were immediately effaced so that all requisite secrecy was secured.

One railway company thought it necessary to cut their drawings into pieces no larger than postage stamps, filling several large sacks. At first we feared this material was wasted, but the Bermondsey Medical Mission discovered that even these fragments formed an excellent substitute for cotton-wool, the price of which was then prohibitory.

During the first six months ending July 31, 1918, the number of pieces, of most excellent quality for surgical use, actually sent to the hospitals was 24,215, in addition to 4,390 still in hand. The lengths varied from 2 to 30 ft., of widths varying from 8 to 48 in. The total aggregate length of this material was between 18 and 19 miles.

Supplies of drawings soon began to arrive from the Scottish railway companies ; but the cost of carriage was so great that I suggested to the Red Cross Society in Edinburgh that they should open a local branch in Glasgow to which all the railway companies and commercial companies north of the Tweed should consign their plans. This suggestion was successfully adopted.

When the War came to an end, and our operations at " Alyn Bank " were closed down, the total result was as follows :

Aggregate length of material distributed, varying in width from 48 in. to a minimum width of 8 in., 60 miles ; aggregate length of smaller pieces not exceeding 24 in. in length, and of varying widths, 61 miles ; making a total of 121 miles. All this represented a value of many thousands of pounds, and it is estimated that every drawing, from the start to the finish, had to be handled seven times.

Another item of war work was the growing of vegetables and tomatoes for allotments. This could not be done without heat, and fuel was, of course, strictly rationed. However, the authorities permitted me to buy the necessary coke : in consequence of this we were able to give free of cost to the allotments many thousands of plants of all kinds.

CHAPTER XXIV

A BURGLARY AND ITS CONSEQUENCES

When I was a child my father was robbed under peculiarly painful circumstances. The wife of his coachman was taken suddenly ill, and, in order to save her life, she and her husband were accommodated with rooms in our house, and the wife was placed under the care of our family doctor. Whilst they were in the house, our silver gradually disappeared—apparently much to the distress of the coachman, who feared he might be suspected as the thief. At last the police were called in, and, as a result of their investigations, they arrested the man, and found upon him pawntickets representing the greater portion of the property. He was prosecuted, found guilty, and sent to prison. This incident so shocked my father that he arranged with one of the leading silversmiths in London to take over his silver, and supply in its stead a service of electro-plate, which would offer no temptation to others in the future.

His example was followed in after years by each of his children. When we came to have homes of our own, we purposely refrained from having silver on our tables, hoping in this way to protect ourselves from the depredations of thieves or burglars. Nevertheless, my house at Wimbledon was threatened no fewer than three times. In the end I found it advisable to have suitable burglar alarms installed.

About the year 1913, as our excellent parlour-maid was leaving our service to get married, it became necessary to engage someone to take her place. Among the applicants was a young woman of education, and gentle demeanour, who seemed in every respect eligible. I met her by chance one day on my return from the magistrates' bench. She was having an interview with my wife in our drawing-room, and I had an opportunity of conversing with her for a few minutes. She told us that her parents were Quakers, and that she was accustomed to attend their meetings: that she desired to get a situation in a house with "a religious atmosphere and influence," where she could have quiet Sundays, without evening dinners or late suppers. She had come up from Worthing, she said, with her mistress Lady V.; that the latter would be glad to give her a good character, and would be at her hotel (one of the best in London) and could see my wife if she cared to call there at 2 o'clock the next day.

Lady Fox thereupon wrote to Lady V., and said she would be at the hotel punctually at 2 p.m. She went accordingly the next day, and was shown into a room where she was presently joined by both the English and Continental managers. The former produced my wife's letter, and asked if it referred to a servant. My wife replying in the affirmative, he declared that the whole thing was a fraud; that there was no such person as Lady V., and that they strongly objected to their hotel being made the meeting-place for servants. My wife of course pointed out at once that she had not fixed the interview. Whilst they were speaking, the hall porter came in, and said that Lady V. had just telephoned that she was sorry she would be twenty minutes late, and would Lady Fox kindly wait for her? The manager seemed puzzled, but said he thought it would be best for her to do as Lady V. asked.

My wife waited for a long time; but no one arrived, and she returned home to find a most extraordinary state of affairs. During her absence the woman had driven down from London in a taxi, had told the temporary parlour-maid that she had seen Lady Fox in London; that the latter had engaged her, and had told her to come down to Wimbledon and ask to be shown how to lay the table for dinner.

Suspecting nothing wrong, the temporary parlour-maid showed her what to do, and where to find the things. The impostor was of course able to take stock of the contents of the safe, where things in the parlour-maid's charge were kept, and doubtless she had opportunities for studying the fastenings of windows and doors. She then returned to London, after inducing the housekeeper to give her money for the taxi.

A warrant was issued for her arrest for obtaining money under false pretences. The detective on being handed the warrant remarked that he had no clue, and hadn't the least idea where to begin his investigation. A few days later, however, a telephone message came from a London police station to say that a young woman had been given into custody by a lady in Park Lane, for having defrauded her. Our detective at once went to the Vine Street Police Station, on the bare chance of the woman in custody being the culprit he was charged to arrest. Fortunately this turned out to be the case. The bogus parlour-maid was brought up before the Court in due course, and received six months' imprisonment, which she served at the Holloway Prison for Women. Having completed this sentence, the woman was again arrested on the much more serious charge of adopting the garb of a hospital nurse, and robbing an invalid committed to her care. This time she was sentenced to three years' imprisonment and was sent to the Aylesbury Prison for Women.

It so happened that my eldest daughter was both the Governor and Medical Officer of Aylesbury Prison—the only appointment in the world of the kind—but evidently the woman did not realise that the Governor of the prison was connected with us. While she was serving her sentence, my wife and I spent the week-end with our daughter at the prison, and on Sunday morning attended Divine Service in the Chapel. During the service one of the prisoners fainted, and had to be removed by the wardresses, and my daughter, in her capacity as doctor, went to examine her. On seeing her, the prisoner exclaimed: "Oh! doctor, I had such a shock, I noticed Sir Francis and Lady Fox in the Chapel! Are you related to them?"

We surmised from the methods of the pseudo parlour-maid that she was probably connected with a gang of thieves and might have had time before her arrest to communicate to her confederates the knowledge she had gained of the interior of " Alyn Bank," and of our belongings there. We were therefore prepared for a possible sequel, and took the precaution to have all the anti-burglar bells and contrivances thoroughly overhauled and put in good order. We then awaited the coming of our " fish " with some interest.

Not long afterwards, on October 7, 1913, at 3.30 a.m. we were aroused by the powerful gong sounding. We hastened downstairs, switched on the electric light, and found the dining-room door leading into the hall open and swinging in a strong breeze, caused by the plate glass in the outer door having been broken and removed. We saw at once that the whole place had been ransacked and that the burglars had bolted.

At 3.31 a.m.—exactly one minute after the alarm gong sounded—we rang up the police on the telephone, and received a reply from the operator in three seconds. His alertness and promptness were due to a curious incident which he afterwards explained to me. At 1 a.m. he said he had been rung up from a " public call-box " in London, and asked " if Sir Francis Fox was at home." This seemed an extraordinary inquiry, and his suspicions were aroused. He resolved to stand by the switchboard, expecting to be called up, so that when he received my call at 3.31 a.m., he put me through to the police station immediately. In four minutes, five constables on bicycles were tearing up to "Alyn Bank," by the two converging roads, and at 3.45 a.m. the men were captured in the Worple Road. They were electrical engineers, they said, going to their work by the 4 a.m. train to London.

Our dining-room presented a curious scene at that unusual hour. We had called our maids, and they had come down in their dressing gowns. The two dogs were rushing about ; the room was brilliantly lighted ; and the police were searching the rooms, and garden. The plate glass had been very ingeniously broken through, and the outer door opened. The burglars had ransacked the room, forcing open drawers and cupboards. They had then proceeded to cut their way through the door into the hall. The keyhole and striking plate had been centre-bitted, the strong hook had been bent straight, and the door opened. This had set the loud gong going and had given the alarm.

At 5.45 a.m. we attended at the police station to enter the charge. It was a wretched morning, pitch dark, with drenching rain, and the tram service had not begun. Some eight or more policemen were ranged round the room with the two burglars in the middle. All their tools, and our stolen property, were being carefully arranged on the table and a list of them was made. I thanked the Inspector, Sergeants, and Officers for their splendid promptitude, telling them that I should report their vigilance to the Chief of the

Police. Our "two friends," I added, now probably appreciated the value of electric gongs. I also referred to the excellent telephone operator, commending his intelligence and discernment. I afterwards made a point of calling the attention of the Telephone Department to the service the latter had rendered.

The burglars were committed for trial at the Old Bailey, and on November 11 the leader X, who was well connected and evidently an educated man, received a sentence of three years' penal servitude. It turned out that he had already been convicted four times for housebreaking. The other man, Y, had only acted as assistant, and was sentenced to twelve months' hard labour.

In giving my evidence I drew the judge's attention to the fact that, although it was a most determined burglary, the prisoners were not armed with any deadly weapons, nor had they maliciously damaged things they could not carry away. This point in their favour evidently weighed in the consideration of their sentences. They both went to Wandsworth Gaol, and a month later, having obtained permission from the Home Office, I visited them for ten minutes in their cells, accompanied by the Governor.

I told X that my object in seeing him was to assure him that I had no feeling of ill-will towards him. Unfortunately for himself, he had chosen for attack a house which contained no silver, nor any articles of great value, and one which was protected electrically. I told him that, if he behaved well during his time in prison, and earned his full number of good marks, his sentence would be reduced from three years to two years three months. He need be under no apprehension, when the time came for his release, that he would be obliged to revert to crime. I promised that I would do all I could to help him and to find him work. " It is kind—very kind," he uttered in a low tone. I entreated him to give up crime. " I've done with it," he said firmly, " and will not touch it again."

As he would have much time on his hands, I exhorted him to employ some of it in *studying*, not merely *reading*, his Bible, and to ask God for His help and guidance.

Before leaving him I spoke about the burglary.

" How long," I asked, " did it take to get through the plate glass ? "

" An hour and a quarter," he said.

" How long to ransack the dining-room ? "

" Half an hour."

" How long to cut through the door of that room ? "

" Half an hour."

" How did you like the hook on the door ? "

" I never had had to deal with a hook before. So soon as we got the door open, the gong went off and that gave us away."

On leaving I shook hands with him and reiterated my desire to assist him. Turning to the Governor, he said in a low voice, " Sir Francis Fox's visit will have done me more good than twenty years' penal servitude."

As a magistrate of forty-nine years' standing I have ventured to give these particulars, in order that my brethren on the Bench may appreciate the splendid opportunities they have of reclaiming the fallen, if they will but follow up the cases which come before them. Needless to say, one must set about such work in a genuinely kind and Christian way. The least touch of the patronising manner is fatal.

We next visited Y, who had acted as assistant to X, and I gave him the same message. Innocently he said, " Will you kindly give me your name and address ? " The Governor laughed—so did I, and then the prisoner.

I said, " You not only know my house, but have been inside it."

" Yes, I know that," he replied, " but I know neither the house, nor the road. I was only taken on for the job."

I was deeply grieved to hear some time afterwards that Y had again got into trouble. He was arrested on a criminal charge in Glasgow and sentenced to three years' imprisonment.

About six months after my first visit I called again at Wandsworth, and found that X had been removed to Dartmoor to complete his sentence. In reply to my inquiry, the Governor said that the man had behaved admirably during his time. He had given no trouble and had earned his full remission. In June 1915 I went to Dartmoor and was allowed to see X before his release. He had had a further remission of three months, or twelve months in all, for his good conduct. He had an absolutely clean sheet. I was left alone with him for half an hour, in the Deputy-Governor's room, with a warder placed on duty outside the window. He gave me his full name and address. His father, who had recently died, had held a good position in a Government Office, and his mother, for whom he had a deep affection, was engaged on important war work. He himself had originally intended to matriculate at London University with a view to obtaining a medical degree. He said he had no "boss" nor gang. I had a straight talk with him, and told him that I had arranged out-of-door employment for him in a concern in which I was interested. I secured for him good lodgings, good work, excellent wages, and introduced him to the Vicar of the parish.

On his release he had to go for his discharge to Scotland Yard. I went there to meet him, but hardly recognised him. His hair and moustache had grown, he was well dressed in civilian garb, and had quite the appearance of a gentleman.

I represented to the Home Office that the rule which required a prisoner to present himself once a month at the police station, or to be visited by a constable at his work, was fatal to his attempts to reform, and ought to be abrogated. I suggested the adoption of the following plan in the case of X. On the first of each month he was to write to me, giving particulars of his work, his lodgings, his pay, etc.; similar letters were also to be written to me by the manager and the Vicar (the only two persons who knew of his antecedents). As soon as I received these three letters I undertook to send them to the police with a covering letter from myself. This was agreed to by the authorities, and as the plan worked admirably the man was never visited by any official.

He worked most assiduously in his new position and was a model of punctuality. No matter how cold or wet the weather, he was always the first to turn up, and he invariably volunteered for any rough or dangerous work that was required. After being in my employ for some five or six months, he came to my office in London, and said he was afraid he would have to leave. The men were getting somewhat suspicious, since he knew little or nothing of the Great War. He had put them off for a time by telling them he had been in the Canadian woods—which was true, but it was twenty years before ! In the end he had to leave and I suggested that he should enlist. This he was unwilling to do, saying that he hated the Army and all military life. Eventually, however, he had to be enrolled and joined one of the most famous territorial regiments. He earned an excellent character from his colonel, major, padre, and sergeants, and before long I received a letter from him, of which the following is an extract :

"I am pleased to tell you I came through my musketry course successfully, and so far I have not one black mark against me. The life which I thought I should dislike I have come to love. But the Army has done more for me than that : it has made me feel a MAN and given me back my self-respect in a way I never felt before. I think it is partly because I was lucky enough to get into this fine regiment, and I fully appreciate my success in being amongst the decent men of the regiment."

He volunteered for the Front several times, and about May 1916 I had a letter from him which I feel is worth giving *in extenso* as an encouragement to others :

"SOUTHAMPTON,
en route.

"SIR :

"I received your very kind letter on Tuesday evening, and received orders at 7.30 next morning for the Front and left camp at 9.50 a.m.

"We have been here the night, and this may be the last opportunity of writing you before I go out to the *Great Adventure*. I should like to take this opportunity of thanking yourself and Lady Fox for all your many great kindnesses and to tell you that I go out there with a heart full of happiness and what is more, bang full of absolute confidence that I shall *make good* there ; and what is more come back to build something on the solid foundation which you and Lady Fox are very largely instrumental in giving me of these great hopes and confidence.

"I am taking the liberty of sending you a photograph of myself, as I thought perhaps you might like to have one. Will you tell Lady Fox I am sorry to say I have not her Bible with me—not because I don't value it, but because I value it too much. I kept it with me to the last and then sent it off home. I have with me a little paper-backed New Testament (of Lord Roberts'). I want to keep hers until I come back.

"Now, sir, I think I have worried you quite enough so will finish.

"With my respectful and sincere hopes that you are well,

"I remain,
"Yours very sincerely,
"X."

On October 13, 1916, I had a letter from his mother announcing that she had received news on October 12 that he had "been killed somewhere in France."

It appeared that whenever any dangerous work or reconnaissance had to be carried out he immediately volunteered for it: and one very dark and stormy night he set out alone with his captain. Both officer and man were afterwards found dead, shot through the head by snipers.

We were at breakfast when the letter arrived, and having read it I passed it on to my wife. We were both silent for a few moments, overcome with emotion, before I said to her, "Neither you nor I ever thought we should be so near shedding tears over the fate of a burglar."

On communicating the news to the Home Office, I received sympathetic letters from several of the officials there, and from the Governors of the two prisons, the burden of them all being "The man has made good!"

CHAPTER XXV

SOME RECOLLECTIONS OF TRAVEL

(1) South America

I have had the good fortune to visit South America more than once, and am therefore able to realise to some extent its size, its magnificence, and its boundless resources. From the sighting of land by the mail steamers at Pernambuco, to the time when the frontier between Brazil and Uruguay is passed, a whole week elapses during which the coast of Brazil is always in sight.

Between the dates of my first and second visits—an interval of some twenty-one years—great developments had taken place. On the first occasion yellow fever was claiming a thousand victims a day in Rio de Janeiro, whereas on my later visits this terrible scourge had been completely stamped out.

In the neighbourhood of Rio de Janeiro a magnificent drive, or Avenida Beira-Mar, had been constructed round the many indented bays lying between the city and the Sugar Loaf Mountain, which guards, as a sentinel, on the south shore the narrow entrance from the sea. This esplanade has a fine footwalk, with parapet on the sea side and trees on the other ; then a wide motor-road bounded by further trees and a walk ; and again, and parallel with these, another motor-road, footwalk and trees. It constitutes the finest drive of the kind in the world and runs for many miles, with a roadway tunnel under the mountain to the open Atlantic.

A rack railway up the Corcovado Mountain enables one to get a splendid view of the panorama of Rio and its superb inland sea. In fact this is without doubt the loveliest place in the world, covered as it is with tropical scenery and vegetation. The comfortable International Hotel, and the hotel at Tijuca, are delightful places at which to stay, and are within easy reach of the beautiful Botanical Gardens.

In the Province of Minas Geraes in Brazil there are great deposits of valuable ores of iron and manganese, and also of diamonds. A range of mountains called Itacolumi gives its name to the sandstone Itacolumite, which has the remarkable quality, for a stone, of flexibility. It is found in a bed or layer in the sandstone quarries, and is generally 6 or 8 in. in thickness ; when a slab is cut out it can be bent, within certain limits, in any direction. No geologist nor scientist has ever satisfactorily explained (although many theories have been advanced) how the particles of sand are arranged to allow of this movement. Similar flexible sandstone is found in India and the Punjab. Some large and good specimens are to be seen in the Mineral Department of the Natural History Museum at South Kensington.

On the coast of Uruguay at Maldonado, Professor Darwin during his voyage on H.M.S. *Beagle* noticed on the sand dunes adjacent to the sea what were apparently a large number of upright sticks protruding from the sand 6 in. or more. Upon examining them he discovered that they were not sticks at all, but tubes of vitrified sand from the dunes, which had been fused by the flashes of lightning during the heavy electrical storms for which this district is noted. They are known as Fulgurites. The explanation of their upright position is, that storms of wind have blown away the loose sand surrounding them, lowering the surface of the sand and leaving the tops of the fulgurites exposed. At Drigg, in Cumberland, similar fulgurites have been discovered, and excavations were made to ascertain to what depth they extended; but at 30 ft. the difficulty of going lower increased so rapidly that the quest was abandoned. The late Mr. C. E. Roche Rowland, British Vice-Consul in Montevideo, kindly gave me some interesting specimens which vary in diameter from a quarter of an inch to an inch. Why these particular sand dunes should be affected by lightning more than other places is a mystery.

Montevideo, the capital of Uruguay, stands in a commanding position at the entrance of the estuary of La Plata, which is formed by the two great rivers, the Uruguay and the Parana. These rivers bring down enormous quantities of sand and alluvial soil, and are responsible for the accretion of the Estuary which is continually pushing the "tail" of the bank nearer and nearer to the sea. Within the period of my first and last visits, the Lightship has had to be moved 15 miles farther down towards the Atlantic, and the approach to Buenos Ayres for ocean-going ships is annually becoming more and more difficult. It is only kept open by the costly method of dredging a deep-water channel through the deposited silt ; and even to negotiate this the Royal Mail Company's steamers have to be built flat-bottomed, without a mid-keel, and their plates scrape on the floor of the Canal.

The vessels of the Pacific Steam Navigation Company, which are exposed to the gales of Cape Horn and Magellan Straits, have to be built on different lines, with deep keels and greater draught, and are consequently unable to go up to Buenos Ayres, but discharge their cargoes and passengers for the Argentine at Montevideo. In the opinion of experienced captains the day is not far distant when the traffic for Buenos Ayres will have to be dealt with by an entirely new port to be built on the coast of the open sea, at or near Samborombon. To abandon good sea-going qualities in their ships in order to negotiate a dredged channel hardly seems to be economically correct.

Considerations of natural safety point in the same direction as those of sound business. The Argentine war vessels, which may be required in any emergency to protect their capital, can only be accommodated at Port Militar, near Bahia Blanca, a distance of 700 miles farther south. It would be a parallel case if our British fleet for the defence of the Channel had to be held in reserve at Scapa Flow in the Orkney Islands, north of Scotland, or even farther away.

Montevideo itself is sorely in need of improvement. Instead of facing the sea with its view, and healthful sea breezes, it turns its back to it, and relegates its fine frontage to the cemeteries, slaughter-houses, rubbish tips, gas works, and such-like. Rather should it emulate Rio de Janeiro in the matter of its fine Avenida Beira-Mar, with its magnificent Boulevard. The proposed construction of "The Rambla" would have provided Montevideo with a fine Esplanade; and the reclamation of a large area of land which could be utilised for the extension of the city would have given it a handsome sea front.

The Port of Montevideo has been laid out on good lines and is partially constructed, but unfortunately the Government were persuaded on economical grounds by the Germans to allow them to construct the breakwater. We have it on good authority that the man who builds his house on sand is a fool, yet the German engineer proceeded to make this mistake. The winds blew, the floods came, and a strong south-easterly gale known as the "Pampero" had a voice in the matter. It only took a few hours to transform what appeared to be a massive breakwater over half a mile in length, into a heap of ruins, to which a detailed photograph hardly does justice. Had an English firm like Messrs. Pearson or Messrs. C. H. Walker been entrusted with the work, it would be standing to this day.

Some distance up the River Parana, in Salto, one of the provinces of Uruguay, are found those very interesting water stones, "geodes" or enhydros, which are hollow and contain water. They are agates in course of formation, the process of their growth having been arrested by the stopping up of the inlets and outlets; these ducts have been crystallised over, and the water imprisoned for untold ages. The formation of these "geodes," which are chalcedony, has been explained as follows. When the lava from a volcano producing black basalt is suddenly cooled, innumerable cracks and cavities are left by the shrinkage. These cavities are filled with water to the extent of a wineglassful or so, containing silica which is deposited in layers of fine crystals. In this way are produced those beautiful parallel lines found in cornelian, onyx, and similar stones, which are generally chalcedony coloured by some foreign substance.

On the River Iguassu between Brazil and Uruguay are the great Falls which are claimed to be the finest in the world, but the height is broken into two cascades. On plan they are in the form of a horseshoe. In some maps they are styled the Victoria Falls — the name given by the ubiquitous Englishman—but for the future they will be known as the Falls of the Iguassu. They will, at some not very remote date, provide electrical power, or as it has been termed "white coal," for lighting and driving great factories.

In June 1922 a steamer, conveying tourists up the Rivers Uruguay and Iguassu, was sunk by an explosion and eighty of these visitors were lost.

The great Docks at Buenos Ayres, built by Messrs. Walker, now furnish one of the main inlets and outlets for the trade of Argentina. A very different state of things existed on my first visit. Owing to the very shallow water the steamer had to anchor some miles away in the estuary, and the passengers were taken off by a steam tug; the tug in its turn had to transfer its load into rowing-boats; and even with their aid, one could only get ashore by being carried on men's backs. The boatman who carried me became chief owner of the various steamship companies running on the great Argentine river, the well-known Nicolas Mihanovich. He recently died a multi-millionaire.

(2) South Africa

When I was in Cape Town I asked Sir David Gill, F.R.S., the Astronomer-Royal of the Cape, if he would allow me to come to the Observatory and look through his telescope. He regarded me rather dubiously, and after a little hesitation said: "Yes, yes, I think I should be justified in doing so—but a lady! never again. A lady visited my observatory the other day. Before she looked through, to prevent her from being disappointed, I explained to her that she would see only one small area of the moon, and that she would notice a cobweb across the field of the telescope. She looked through and exclaimed, 'Wonderful! beautiful! but, Sir David, I had no conception that any telescope was powerful enough to show the cobwebs in the moon.'"

Before I left, Sir David Gill very kindly gave me four lantern slides of "the invisible stars," so called because the human eye cannot see them. The first had been exposed for five minutes to a dark portion of the midnight sky in "η Argus," and the plate revealed many stars which neither the human eye nor the most powerful telescope could ever see. This is due to the fact that the photographic plate is far more sensitive than the human eye. No. 2 plate had been exposed three hours, and one can see all the stars on No. 1, with the addition of many more. Again, No. 3 had had an exposure of twelve hours, that is six hours each night for two consecutive nights. No. 4 had been exposed twenty-five hours, requiring exposure on three or four consecutive nights, with the result that the plate is a mass of blazing suns, each one of them probably attended by its own satellites and worlds. In fact, it is a most merciful provision that the retina of the eye is capable of seeing only what we do see. Were it as sensitive as the photographic negative, the whole dome of heaven would be a mass of blazing, blinding light.

I stayed the week-end with a leading Government official at Wynberg. On driving up to his house, the door was opened by a tall, nice-looking black maid, who spoke English perfectly, and with a cultured voice and pronunciation to boot. She waited at table, and came to morning prayers. In the early morning she brought me a cup of tea, and spoke in a gentle manner like a lady of refinement. On the Sunday morning she accompanied us to Divine Service. I remarked to my host what an excellent servant she was ;

he said: "Yes, and more than that, she is a Princess." Her father was King of —— and had great wealth in cattle, ostriches, etc. He had consulted the British Government over her education, with the result that at an early age she was sent to Cape Town and placed under first-rate English governesses and teachers, until she was eighteen or nineteen years of age. When her father died, the people sent for her to return to her home, and become the Queen. But when she found she would have to revert to heathen rites and ceremonies, she said this was impossible. She had learnt English, but she had also embraced the Christian faith, and she could not give it up. In the end they decided not to place her on the throne, and disinherited her. So she became a parlour-maid in my friend's house.

A somewhat unusual incident occurred on our mail steamer as she was leaving Cape Town for Southampton. We were well out to sea, when the third-class steward came to the captain and said they had found a "stowaway" on board. He had gone to one of the third-class berths, thrown the baggage of the rightful owner on to the floor, and taken possession. The captain summoned him to his cabin on the bridge, and asked him to show him his ticket, but he had not one. The "stowaway" was a tall, powerful fellow, and it was discovered that he was abandoning his wife and six children, and leaving them to their fate in South Africa. Naturally the captain was furious. He told the man that unless he paid his fare (£12) before night he would be placed in a cell for the voyage. The man slunk away, but instead of returning to the third-class quarters, he passed along the first-class gangway, and entered the smoking-room where a number of officers were talking. He saluted them and said : " Gentlemen ! they have discovered a poor boy on the steamer, a stowaway for England, and I have been asked to raise a subscription to defray his fare—£12." The passengers were touched with sympathy ; one colonel threw him four sovereigns, another two, and in less time than it takes to record the incident, the man obtained the full £12. Returning to the bridge, he said to the captain with an insolent air : " Half an hour ago you threatened to put me in irons if I did not pay my fare. Well, there is £1, there are £2," and so on to the full £12. " Now, give me my berth." The captain had no choice but to comply.

He was a most objectionable man, boycotted by all the passengers, insolent to the officers. When the smoke-room occupants heard they had been cheated, they were naturally greatly angered, and decided to prosecute him on arrival at Southampton for obtaining money under false pretences. But they found that to take proceedings against the man would detain them for a day in Southampton, so they had to drop his prosecution, and he landed a free man to prey upon the community in England.

Another strange incident occurred on one of my long voyages in 1897. I was returning from the Cape in one of the fine mail steamers, and a fellow-passenger, whom we will call Mr. W., was going to England to spend Christmas and the New Year with his wife and children at his home near London. He intended to return to South Africa at the end of the following January. Mr. W. was a well-known engineer in Westminster, formerly of the London and North-Western Railway, and had been on many occasions in the service of my firm. He had been in a remote part of Africa engaged on survey work for a South African Company and had lived on tinned food almost exclusively, in consequence of the crops and herds having been destroyed by long-continued drought, by locusts, and by rinderpest. The want of fresh food and vegetables had affected his health, but he was hoping that the voyage to England, combined with a restful holiday, would set him up again. On the voyage he sat at the doctor's table and each day seemed to improve in colour and appearance. He and I often promenaded the deck for exercise: or we sat in deck chairs talking over past experiences.

After calling at Madeira on December 15 we ran into heavy weather. However, it seemed to suit him, and on the evening of Thursday, December 16, he rose from the table about 8 p.m. in good spirits, saying, "Well, doctor, I have made the best meal since I left England a year ago." The doctor replied that he was rapidly improving and would arrive home quite restored. About 8.30 p.m. the captain came to me and said: "I believe you are a friend of Mr. W's. I fear he is very ill. Could you go down to his cabin?"

I went down to his cabin and was shocked to see him lying on the floor in a state of insensibility. A steward was at his feet with hot-water bottles, and another steward at his head with ice bags. I was told that he had suddenly fallen on the floor in an apoplectic fit, and had never regained consciousness. What struck me most of all was that his hair had turned *white*. I at once decided not to mention this fact to anyone, not even to my wife or children, as it might prove distressing to his wife, if it should ever come to her ears.

The poor man passed away quietly about midnight on December 16, and as we were so far from England the captain decided to perform the burial at sea at 8 o'clock the next morning, Friday, December 17, before any of the passengers were about. He asked me to be the chief mourner and the official witness. As a last mark of respect to my friend I consented, and in the morning we consigned his body to the deep, the sailors, steward, and officers attending in full-dress uniform. The service was conducted by the captain during a heavy gale of wind, in a most reverential manner.

At that date wireless telegraphy was not in use, and it was impossible to transmit any message home. The passengers, therefore, asked me to break the news to Mrs. W. on our arrival in England on Sunday, December 19. Unfortunately I missed her, and she received the news from another passenger, a stranger, on the arrival of the train at Waterloo Station on Sunday.

The news had, however, been anticipated in a remarkable way. Mr. W's aged father, who lived near Southampton with an unmarried daughter, coming down to breakfast on the morning of Thursday, December 16, said to his daughter, "I have had a curious dream. I have seen my dear son floating on the waves."

She, in order to reassure him, replied, "Oh, no! he will be home on Sunday next."

"No, he won't; he has died and been buried at sea."

The daughter of my departed friend had also dreamt three times in succession on the Wednesday night that she saw her father lying on the floor of a room which she did not recognise. She called him each time, but he gave no answer. There was a man at his head and another at his feet, and his hair was white! A gentleman friend also dreamt that Mr. W. had died on the voyage home.

After receiving the news of her husband's death, as Mrs. W. was very anxious to cause as little shock as possible to the old man his father, she consulted the Vicar of her parish, and he suggested that she should send two telegrams to Southampton. The first was to say that her husband was dangerously ill, and the second to follow in an hour stating that he had died. When the first telegram reached the old man, he merely smiled and said, "It's very kind; it has been sent to break the news gently, but I know he has died."

Surely a merciful provision, this—the sad intelligence conveyed in a dream, and mitigating the shock which the sudden announcement of the death would have caused. I was pressed by the psychical research people to allow them to publish this incident in their journal, but declined.

In November 1897 when I was returning from the opening of the Cape and Cairo Railway as far as Buluwayo, I was a guest of Sir Henry de Villiers (afterwards Lord de Villiers), the Lord Chief Justice of the Cape, near Cape Town. In course of conversation he said he would be personally obliged if I would go to the Parliament Buildings, and inspect a remarkable map which had been found in the Library and deserved, as he thought, to be widely known. It proved that the geography of the interior of Africa had been to a large extent discovered and published 250 years ago. Naturally I complied with his request, and on November 20 the map was produced for my inspection by Mr. Horne, the Surveyor-General, and Mr. Liebhardt. It bears the date 1662 and a statement that it was printed in Amsterdam by Johannis Blauer. It shows two large lakes or Nyanzas (though much out of their true position), and states that they give rise to the tributaries of the Nile and also of the Lualaba and Congo, thus answering the questions which had long been asked as to the sources of these great rivers. The upper waters of the Congo are shown as flowing north, then turning with a great bend to the west, and eventually falling into the South Atlantic Ocean.

Meeting Sir Henry Stanley, one of the British South Africa Company's guests at the opening of the railway, I suggested to him the importance of this information, and induced him to visit the Library and inspect the map. When I next saw him he expressed astonishment that such a map had ever been produced, and added that had he known of its existence prior to his journey down the Congo it would have saved him much suffering, and also the lives of many of his men. It is evident from Sir Henry Stanley's *Through the Dark Continent* that when he was descending the Lualaba he was entirely ignorant whether the river would prove to be a tributary of the Congo, the Niger or the Nile. Had he known that he was likely to descend the Congo he would have made other plans, in order to avert the starvation and fighting which nearly brought his expedition to an untimely end; he could, for example, have arranged for a relief vessel to meet him lower down the Congo.

Other copies of the same map exist in the British Museum.

Sir Henry Stanley had chambers in New Bond Street, and I frequently visited him there. On each occasion the door was opened by a little African boy, with ebony skin, ivory teeth, and a bright smile—a charming little fellow. Some time after, on our voyage out to the Cape, I asked Sir Henry about this little boy, and he told me the following remarkable story:

"On one of my expeditions I rescued him from slavery. Being an orphan, he became my servant. He was a sharp intelligent lad, and I brought him to Europe with me more than once. His name was Biruti (meaning gunpowder). On my last voyage up the Congo I anchored off his native town, where the river is over a mile in width. The King came out in his war canoe, but would not come within a hundred yards of my vessel, so I told Biruti to hail them and assure them we were friends. The boy accordingly shouted out to the King: 'Come here! the great white man wishes to be your friend and to see you. I am Biruti your brother.' The reply came: 'I once had a brother of that name, but how can I be certain that you are Biruti?' After a time they mustered up courage and came. As soon as the boats touched, the King and Biruti rushed and embraced each other, dancing and crying for joy. When it was time to leave I gave Biruti his choice between remaining with his brother or coming on with me. He hesitated, and seemed very loath to leave me. But finally he said that though he would be sorry to leave the great white chief he should like to remain in his own home. So the attractions of home overcame him and he was left behind. Within a month, the people of that part finding that Biruti had learnt so much from his visits to England, and that he had seen the Great White Queen, held a great palaver, and decided that for the benefit of his tribe he must die and be eaten, so that his blood would be distributed throughout the whole tribe!"

So it came about that this nice little fellow who had opened the door to me in Bond Street was sacrificed for the benefit of his people!

CHAPTER XXVI

JONAH AND THE WHALE

THE story of " Jonah and the whale " is one which has proved a stumbling block to many persons. The following incident, which occurred in the autumn of 1914, may be of interest to such sceptical people.

A certain friend of mine, the late Rev. D. MacCalman, was travelling on a passenger steamer to the far north of Great Britain, and opposite to him at meals sat an old man between seventy-five and eighty years of age, with beautiful locks of silvery-white hair. He began a conversation by saying :

" I suppose you are a minister ? "

" Yes, I am."

" You therefore believe the Bible and its miracles ? "

" Certainly."

" Even that about Jonah and the whale ? "

" Certainly, although the actual words used were ' a great fish.' "

" It is a mere fairy tale, for a whale feeds on animalcules, and has such a narrow throat that to swallow a man is an impossibility."

" About that I can make no reply, but, as our Lord quoted the incident Himself, it is quite sufficient for me."

At breakfast next day, and at lunch again, "Jonah and the whale" cropped up, and our friend said he was getting a little tired of the subject.

After forty-eight hours' journey the vessel arrived at its destination, a small town with a single hotel of modest pretensions, and here it was to remain for thirty-six hours.

Next morning Mr. MacCalman informed his fellow-passenger that he had just discovered that there was a whaling station within a mile, and they agreed to walk over and see it. The manager, a fine, tall man, kindly showed them over the works, and they saw the boats and harpoons, the guns and bombs, the slipway up which the fish were hauled in, the boilers for melting the blubber, and all the apparatus for barrelling and packing.

The gentleman asked how many kinds of whales were caught, adding on his own account that they fed on animalcules. The manager replied that there were four kinds—the fin, the bottle-nose, the blue, and the sperm whales. "But as to feeding on animalcules," said he, "they are animalcules of some size, as we can tell by cutting open the stomach." Asked what was the largest thing they found, he said, "the skeleton of a shark 16 ft. in length." The old gentleman objected that as the throat was so narrow it was impossible for such a large object to pass; but the manager smiled and said, "Narrow! the throat of the sperm whale can take lumps of food 8 ft. in diameter."

The minister then asked the manager if he believed in the story of "Jonah and the whale," and he replied:

"Certainly. It was of course a miracle how Jonah was kept alive inside the fish, but, as to the possibility of his being swallowed, there can be no question."

On their return to the hotel, the old man was very taciturn, and continued so during the dinner. He seemed depressed. After dinner they parted, and went to their rooms having bid each other farewell, as the steamer was to leave at 6 a.m. the next morning, and our friend would go with her.

Just as Mr. MacCalman was about to begin to undress there was a gentle knock at the door, and the old man entered. He sat down quietly at a table, and said: "Mr. MacCalman, before you leave I am desirous of saying something to you. What we have seen to-day has been a complete eye-opener to me. I was brought up as a boy and a young man in an agnostic family, and taught to deride the Bible and its miracles. 'Jonah and the whale' was often the subject of merriment and of our disbelief. I then went to Germany as a medical student, and attended certain lectures not connected with my profession which unsettled my belief in God, and I have been sad and dissatisfied ever since; I am now an old man and it's almost too late to change." So saying he buried his head in his hands, with his arms on the table, his beautiful silvery locks falling over his face and hands, and sobbed like a child. What followed cannot be related.

I add another story of a rather different character. I have been fortunate enough to get particulars of a well-accredited instance in recent times, of a man being swallowed by a whale and being rescued alive after remaining many hours in its stomach.

Two separate accounts have been given of the event—one evidently by the captain of the whaler ; the other probably by one of the officers. The incident was carefully investigated by two scientists—one of whom was the late M. de Parville, the scientific editor of the *Journal des Débats* of Paris, well known as a man of sound judgment and a careful writer. He unfortunately died during the late war. I therefore applied for information to the subsequent editor of the paper, a gentleman noted for his kindness and ability. He answered that as he was engaged in the War he could not lay his hands on the papers, but when he returned to Paris, he would search for them as he well remembered them being discussed during M. de Parville's life. Rather more than twelve months later, November 2, 1919, he wrote to me as follows :

'Eureka ! . . . Having gone over a very large number of documents, I have now the good fortune to find the one you want—something even better than what I expected . . . an English translation which M. de Parville had himself used."

The account briefly is as follows :

In February 1891 the whaling ship *Star of the East* was in the vicinity of the Falkland Islands, and the look-out sighted a large sperm whale three miles away. Two boats were launched and in a short time one of the harpooners was enabled to spear the fish. The second boat attacked the whale, but was upset by a lash of its tail and the men thrown into the sea, one man being drowned, and another, James Bartley, having disappeared could not be found. The whale was killed and in a few hours the great body was lying by the ship's side, and the crew were busy with axes and spades removing the blubber. They worked all day and part of the night. Next morning they attached some tackle to the stomach, which was hoisted on to the deck. The sailors were startled by something in it which gave spasmodic signs of life, and inside was found the missing sailor doubled up and unconscious. He was laid on the deck and treated to a bath of sea-water which soon revived him, but his mind was not clear, and he was placed in the captain's quarters, where he remained two weeks a raving lunatic. He was kindly and carefully treated by the captain, and by the officers of the ship, and gradually regained possession of his senses. At the end of the third week he had entirely recovered from the shock and resumed his duties.

During his sojourn in the whale's stomach, Bartley's skin where it was exposed to the action of the gastric juice underwent a striking change; his face, neck, and hands were bleached to a deadly whiteness, and took on the appearance of parchment. Bartley affirms that he would probably have lived inside his house of flesh until he starved, for he lost his senses through fright and not from lack of air. He says that he remembered the sensation of being thrown out of the boat into the sea, and of dropping into the water. Then there was a fearful rushing sound which he believed to be the beating of the water by the whale's tail—he was then encompassed by a great darkness, and he felt he was slipping along a smooth passage of some sort that seemed to move and carry him forward. This sensation lasted but a short time and then he realised he had more room. He felt about him and his hands came in contact with a yielding slimy substance, that seemed to shrink from his touch. It finally dawned upon him that he had been swallowed by the whale, and he was overcome by horror at the situation. He could easily breathe, but the heat was terrible. It was not of a scorching, stifling nature, but it seemed to open the pores of his skin and to draw out his vitality. He became very weak and grew sick at the stomach. He knew there was no hope of escape from his strange prison. Death stared him in the face. He tried to look at it bravely, but the terrible quiet, darkness and heat, combined with the horrible knowledge of his environment, overcame him. The next he remembered was being in the captain's cabin.

According to the record, the skin on his face and hands never recovered its natural appearance, but the health of the man did not seem affected by his terrible experience. He was in splendid spirits and apparently fully enjoyed the blessings of life that came his way. The whaling captains say that it frequently happens that men are swallowed by whales who become infuriated by the pain of the harpoon, and attack the boats, but they have never previously known a man to go through the ordeal that Bartley experienced and come out alive.

It is stated that on the return of the vessel to England, Bartley went to a London hospital to be treated for the injury to his skin—but what occurred is not in the record. He was known to be one of the most hardy of whalemen.

M. de Parville, one of the most careful and painstaking scientists in Europe, concluded his investigations by stating his belief: "that the account given by the captain and the crew of the English whaler is worthy of belief. There are many cases reported where whales, in the fury of their dying agony, have swallowed human beings, but this is the first modern case where the victim has come forth safe and sound. After this modern illustration I end by believing that Jonah really did come out from the whale alive as the Bible records."

The Curator of a large Museum, in reply to a question I put to him as to the temperature of the blood of a whale, said it was about 2·5 Centigrade above the temperature of the human body—which, in the Fahrenheit scale, would be 104·6°, or high fever heat. This provision was doubtless made to enable these mammals to resist the cold of the Arctic and Antarctic Seas.

As the story of Jonah is often a source of merriment with some persons—and a matter of difficulty to many more—it seems only right to show that the story is not necessarily absurd. It should not be forgotten, that it has the seal and imprimatur of no less an authority than our Lord Himself. "For as Jonah was three days and three nights in the whale's belly: so shall the Son of Man be three days and three nights in the heart of the earth" (St. Matt. xii. 40). If, as some allege, this reference to Jonah is only allegorical, it follows as a natural sequence that the reference to our Lord is also allegorical, and that is not a conclusion which Christians can accept.

Should any reader desire to test the accuracy of the statement as to the swallowing capacities of a whale, he has only to visit the Natural History Museum and ask for information from the leading officials of the Whale Department.

In conclusion I would ask the question whether it is not time that some steps of an international character were taken to prevent over fishing, and the eventual extinction of these splendid creatures? At present, instead of small sailing-ship whalers, steamers of 7,000 tons are fitted out as floating work-shops equipped with every conceivable appliance for sweeping the seas of whales. The industry ought to be placed under proper control; already it is believed that certain kinds have been exterminated, and the same fate will overtake the remainder if measures are not taken to preserve them.

CHAPTER XXVII

BREAD AND FLOUR

Bread and flour? What place can domestic articles like these have in the reminiscences of a civil engineer? Well, my readers have been warned in the Preface that towards the end of my book I should allow myself considerable freedom in my choice of subjects. This happens to be a matter in which I have taken a peculiar interest; and if the reader dislikes the whiff of an old controversy, let him skip this chapter and pass on.

According to the returns of the Board of Trade, bread and flour constitute nearly half of the labouring man's solid food, and almost the sole diet of many poor children, and it is therefore most important, from a national point of view, that each of these commodities should be produced, and that the public should know and ensure that they are produced, in as pure and nutritious a form as possible. It was with this aim that the Assize of Bread was instituted at an early age in our history, and in the year 1202 a proclamation was made regulating the quality and price of bread. Four "discreet" men were appointed to carry out the provisions of this law, and the pillory and tumbril were the punishments awarded to those who broke or evaded it. It is to be feared that, were the Assize of Bread still in force, the modern system of flour milling would, to some extent, offend against it, and render some of our millers liable to its penalties.

But before either bread or flour, comes the wheat from which they are made. Few amongst the general public (others than farmers) think how strange a plant it is.

Wheat is a tender annual requiring constant attention, and if left uncared for, and uncultivated, it dies out. For instance, let a field be sown with wheat and then let it be neglected ; the wheat plant will grow up and shed its grain, and this may possibly survive a mild winter, but in the course of two or three years there will be no trace left of the crop or of the plant. Very different is this from the herbage for cattle, which grows everywhere unasked, and which covers very quickly any waste ground. Again, though wheat is a tender annual, it is remarkable for the very wide range of latitude in which it will grow. It is cultivated in the hot plains of India ; it grows in the cold of Siberia, and even within two hundred and fifty miles of Klondike. It is believed there is no other plant which is adapted to such great changes.

Wheat requires the ground to be prepared for it, at an enormous expenditure of labour. To till even one acre with furrows 12 in. apart the ploughman with his plough and team has to travel eight miles and a half ; if the field be fifty acres in area, he must make a journey of 425 miles. The grain has then to be drilled into the soil, and the field has to be rolled and harrowed. When the time of harvest arrives it has to be reaped, gathered and stored, thrashed, and ground into flour. Finally it has to be baked and made into bread to gladden the heart of man. We are told " In the sweat of thy face shalt thou eat bread ; " and this is strictly and literally true.

It is noticeable that the value of a crop of wheat depends not only upon the quality and quantity of the grain, but also to some extent upon the crisp, bright, glassy character of the straw. The straw-hat trade of Luton and Dunstable, and other places in the neighbourhood, depends upon the fact that the straw used for plaiting is grown on the adjacent chalk land. The plant has great affinity for the silica in the chalk and flints, and uses it for coating the outside of the stalk with that beautiful glass-pipe covering. And it is due to this fact that America, although she grows such enormous quantities of wheat upon her alluvial lands (having no chalk land), has to send to England so far as I know for straw, through which her people consume their iced drinks, the straw being stiff and airtight, and therefore more suitable for the purpose than their own.

If a grain of wheat be cut in half and examined under a microscope, it will be found that beneath the outer covering which constitutes the bran and " sharps " there are two divisions. The larger one of these contains the white substance or flour, and the smaller, the germ or embryo of the future plant. It is the germ that provides in great measure the colour, the flavour, and the nourishment of the wheat. It is rich in proteid and fat, and its presence or absence in the flour makes a great difference between bread which is palatable and nutritious and that which is comparatively tasteless and valueless as a food.

From the earliest ages until modern times, our ancestors had the wisdom so to grind the grain that the resulting flour contained the white substance as well as the nutritious elements of the germ. To this end they employed horizontal running stones—the upper and nether millstones of the Bible. From these issued a flour, wholesome and full of nutriment, but in colour, owing to the golden tinge of the seed-germ contained in it, not a dead white. This was the flour which for centuries was used to make the good old-fashioned home-made bread, which went to make our ancestors what they were.

Many of us can remember the introduction about forty to fifty years ago of "pure white Hungarian flour," and how it originated the demand, first of our housekeepers and cooks, and afterwards of our working-classes, for white bread. To enable the baker to supply this very white bread to the public, it became necessary for the miller to provide white flour. This could not be achieved by the use of the old-fashioned horizontal grindstones, which by disintegrating the germ tinted the flour. It was obvious to the miller that to produce the white flour demanded the colouring germ must be eliminated from it at the earliest stage of grinding, and this he has succeeded in doing most effectually. The old upper and nether stones are replaced by steel roller-mills. The first pair of steel rollers do not grind the berry; their business is to crack the wheat and then to roll the germ into little discs, which do not go to make the flour at all, but are sifted out by sieves of silk. The little discs of nutriment are used for various purposes; some of it is bought by certain patent bread companies, but the bulk goes to feed pigs and cattle, while our children are regaled upon the less nutritious white loaf.

The material so separated from the flour is termed by millers *offal*, which is a wrongly applied word, and one much to be regretted, as it conveys to the minds of people exactly the converse of the fact. According to the dictionaries, offal means "the rejected or waste parts of a slaughtered animal, a dead body, carrion, that which is thrown away as worthless or unfit for use, refuse, rubbish." This is far from being true of the miller's "offal," as such constitutes the richest, the most valuable and most nutritious portion of the grain. After the elimination of the "germ" by additional grindings and siftings, the superfine white flour is produced. Compared with stone-ground flour it contains less percentage of the original wheat (probably 68 to 72), requires more costly machinery and more elaborate processes, and when finished is a more expensive and less desirable product.

In 1904 I wrote a letter on this subject to *The Times*, from which I take the following passages:

"I was informed a few weeks ago by a gentleman who owns large flour-mills, which produce 50,000 tons of flour annually, that the craze for white bread is being carried to such extremes that at the present moment many of the millers are putting up expensive machinery for the purpose of actually bleaching the flour. This is being done by ozone and nitrous acid ; the object being to make an artificially white bread, and to enable grain to be used which would otherwise give a darker colour to the flour.[1] . . .

" It is the opinion of many who can speak with authority on the subject that bread, instead of being as formerly the ' staff of life,' has become, to a great degree, an indigestible, less-nutritive food, and that it is responsible, amongst other causes, for the want of bone and for the dental troubles in the children of the present generation.

" It is doubtless true that the variety of food now obtainable in a measure compensates, in the case of those who can afford it, for this abstraction of phosphates ; but I think I am justified in stating that every medical man, if asked, will give it as his opinion that very white bread should be avoided and that ' seconds ' flour, now almost unprocurable, should alone be used either for bread or pastry."

The Lancet remarked :

" We should be sorry for the person who tried to subsist entirely upon the modern uninviting loaf, made from blanched roller-milled flour."

In *Food and Dietetics* Dr. Robert Hutchinson says :

" In rejecting the germ and bran the miller undoubtedly discards some of the most useful

[1] An extract from a trade circular sufficient to prove the undesirability of the method is appended :

" The commercial advantages of bleaching flour may be obtained, firstly, by using a *cheaper wheat* mixture ; secondly, by increasing the higher grades of flour . . . and we are able to greatly improve the colour and value of even low-grade flours." —*Trade Circular*, 1904.

chemical constituents of the wheat. A very white loaf means a loaf in which starch is at a maximum and proteid at a minimum, and that is certainly not desirable."

Not long ago I visited some flour mills in which one part was still using the old-fashioned stones, the other portion of the establishment being devoted to roller-grinding. The official in charge of the former expressed his opinion that roller-grinding and abstraction of the germ ought to be prohibited by Act of Parliament. The foreman of the roller-grinding department, on the other hand, on being asked what advantages accrued from roller-grinding, replied, "It makes such superior flour." To the question what he meant by superior flour, he answered, "It is much whiter." He was next asked which was the more nutritious. "That," said he, "is quite another matter." The discussion was finally clinched by my asking him upon which flour he fed his own family. His reply was an eloquent testimony to the truth, for he said, "I feed them upon stone-ground flour."

After working on the problem of better bread for a considerable time, I found that Miss May Yates and Mr. Stephen H. Terry, formerly Engineering Inspector to the Local Government Board, were already engaged in a similar crusade.

Attention was called to the evils of roller-grinding by Mr. Stephen H. Terry in a letter written to *The Lancet* so long ago as June 10, 1882.

To Miss May Yates, as Hon. Sec. of the Bread and Food Reform League, the nation owes a deep debt of gratitude for her ungrudging and ceaseless labour to secure proper flour, and to stop the unwarrantable polishing of rice and pearl-barley.

In recent years a new and powerful argument has been given to the bread-reformers. It has been discovered that the vitamines of wheat exist chiefly in the germ and the outer part of the grain, the very parts which, by roller-milling, are removed in producing white flour. The word "vitamine" has only come in of late years, and as yet the subject is not fully understood. The existence of vitamines was first discovered at the Lister Institute. They appear to be the vitalising elements in all food-stuffs. They can be extracted by means of alcohol and are not destroyed by cooking. It is evident, at any rate, that the importance of any ingredient in food is not to be measured or judged solely by its percentage. Some ingredient of microscopic size, and almost imponderable, makes all the difference between wholesome and unwholesome food.

Whenever I travel in foreign countries, instead of using the fancy white breads usually supplied to hotel guests, I invariably endeavour to purchase the bread made by the peasantry and for the working-classes. It is more nutritious and much more pleasant to the taste.

A working-man, who recently adopted the farmhouse bread, said that no one in his senses having once tasted it would return to the very white loaf; the former was far sweeter, more nourishing and satisfying, and a loaf of it would feed more children.

There is no branch of the trade in which greater ingenuity and skill have been employed than in milling. No one who has not seen the operation can have any idea of the state in which the grain too often is delivered to the miller. The grain is gathered, maybe in some distant part of the world, by reaping machines and self-binders. These latter tie the sheaves round with iron wire, and this, in thrashing, frequently gets mixed up with the grain. It is then shipped, often in a dirty condition, with a proportion of soil, sand, and stones, and on reaching Great Britain is stored in granaries. These consist generally of vertical bins, and as they are used for all kinds of cereals, it is inevitable that a small quantity of other kinds of grain becomes mixed with the wheat. But now the miller appears on the scene, with a number of most ingenious machines, which seem almost to be endowed with human intelligence. In the first place, all such rubbish as bits of rope and string, stick and straw, are taken out ; in the next, the grain passes over magnets which attract to themselves all the pieces of iron, wire, nails, screws : how, one wonders, did such materials ever get in ? The next series of machines carefully pick out and deposit in separate sacks such foreign substances as maize, oats, barley, cockle, beans, peas, etc., by which time the grain consists merely of the desired wheat. But it has still to be freed from the soil and sand of the prairie, and for this object it is washed in cold or warm water, and afterwards dried by means of hot air, by which time it is clean and bright and ready to be ground.

Up to this point there can be nothing but admiration for the miller of to-day. It is the mistaken ingenuity bestowed on the subsequent processes of refinement which we bread-reformers deplore. We do not desire to abolish roller-grinding, as this machinery has since been devised to make excellent flour, provided the desirable ingredients are not extracted.

When Tennyson wrote "Maud" he described what was then a prevalent practice:

> "Chalk and alum and plaster are sold to the poor for bread,
> And the spirit of murder works in the very means of life."

This was done to secure the whiteness of the loaf, any duskiness being then attributed to dirt in the flour. But this evil has, it is believed, now passed away. Whiteness is not now attained by the addition of adulterants, but by the abstraction of the most valuable constituents of the wheat.

Let there be no misapprehension on this point. The desirable bread—that is, a loaf which contains the phosphates and the germ—is still a white bread; but it is not the snow-white anæmic material which has been emasculated and impoverished by the abstraction of all ingredients not absolutely white. The object to be aimed at should be, simply, to reject the bran, and to retain in the flour some of the inner coating of the grain, the fine "middlings," and the germ. Only out of such flour can real bread be made. It is not snow-white, it is true. If people insist on having the snow-white loaf, let them have it by all means—but it should be sold under some other name. Let the name of "bread" once more come to denote the genuine, and not the counterfeit, Staff of Life.

ALYN BANK GARDEN.

The distant view of Surrey Downs—Leith Hill (21 miles away), Banstead, Epsom, and Leatherhead.

ALYN BANK GARDEN.

Narcissus on rockery near pond.

CHAPTER XXVIII

A WIMBLEDON GARDEN

Between the years 1887–92 I lived at that delightful home Mount Alyn, Rossett, in Denbighshire in order to be within easy access of Liverpool where we were carrying out various important works, many of which I have described in Part I of this book.

I have told in Chapter IV how one day I received a telegram from my friend the late Lord Wharncliffe asking me to meet him at Manchester, and how I was entrusted by him with the laying out and construction of the proposed London extension of the Manchester, Sheffield and Lincolnshire Railway, now known as the Great Central Railway between Rugby and Marylebone.

This meant a great uprooting for my wife and family. It would have been impossible for me to superintend the work from a point so far distant. We had therefore to move immediately to London, and to leave "Mount Alyn" with all its beauties, conveniences, and associations. I bought a house at Wimbledon called "Allan Bank,"—a name which I promptly changed to "Alyn Bank," by way of carrying on the old traditions.

The garden at our new house was most unattractive. There was nothing of interest in it, but it had a south aspect, a most important recommendation. It was a rectangular plot of ground of about $1\frac{1}{4}$ acre—with nothing growing in it but some scarlet geraniums, yellow calceolarias, and lobelias—a type of gardening I could never tolerate. There were a few shrubs around the sides and some young forest trees, which thickened in a few years' time to shut out the sun and dominate everything.

But now, after a residence of over thirty years, it has earned the well-deserved title given to it by the late Curator of Kew, who called it "a miniature Kew Botanical Garden."

The soil is hard, dry, uncompromising gravel, and has demanded constant attention. One of the first steps I had to take was to appoint a capable and energetic and at the same time an educated gardener with whom I could work with pleasure.

I found what I wanted in Mr. John Richards, F.R.H.S. When after the first few years I decided to make an Alpine Garden, our success was in no small measure due to him. But for him the garden would never have become the pleasant and attractive place it is now. I decided that so far as it was possible it should be a rock garden—with a natural and informal water-lily pond; that all strong-growing forest trees must be removed so as to admit the sun to every part—and at the same time to remove all their roots which would, no matter at what distance, rob the borders of their richness and moisture.

I felt that before he could cultivate Alpines successfully my gardener ought to see them growing on the mountains in Switzerland, and my wife and I invited him to accompany us there for some ten days. This was again followed by a second visit by him and his wife to another part of Switzerland. We have also studied many of the best Alpine Gardens in England, and gathered much information from them.

The question of suitable rock soon cropped up. It was important that it should be weatherworn and more or less decomposed and disintegrated. If recently excavated rock from quarries is used, many more years of oxidation are necessary before the plants can assimilate the stone.

I obtained new red sandstone from some of our cuttings in Lancashire; tufa from Derbyshire; limestone from the Lias formation; and drift boulders from the Glacial Drift deposits at Robin Hood's Bay in Yorkshire.

It is curious to trace the origins of these drift boulders.

During the epoch when Great Britain was under snow and ice, a great glacier trailed its moraines over the face of the country. These moraines contained representatives of all kinds of deposits, from the black basalt of North Ireland, to the shap granite of West Lancashire and Cumberland. When this glacier melted, it dropped its burden of soil and rock over the east of Yorkshire.

The supply of good soil was a great difficulty. I soon came to the conclusion that the very best which can be obtained is the "top-spit" of a rich old pasture field. Care has to be taken, however, to sterilise it from wireworm, multipedes, and the like.

The next point was the construction of the lily-pond. As our ground was gravel and very porous it was self-evident that no amount of puddling with clay would retain the water. Hence we were compelled to make the pond entirely of cement concrete.

It is of a pleasing irregularity in shape and is so constructed that the concrete itself cannot be seen. The rain-water from the roofs of the house and stabling is all collected into a large underground tank, the overflow from which runs into the pond, thus providing a first-rate supply of soft water for the plants.

In our garden we laid down a law upon which we have always worked—that all attempt at formality, all straight lines, must be "taboo." We abolished altogether the system of bedding out, the borders we filled with herbaceous plants disposed without any regularity, but contrived to produce a complete succession of blooms through all the seasons. First comes the early yellow aconite, then crocuses and snowdrops, followed by all the narcissi and daffodils. After these come all the varieties of sweet alyssum, the many Aubretias, the Alpine and other varieties of Dianthus, till the midsummer sun brings a fresh range of plants into flower—amongst them the *Gladiolus primulinus* with all its glorious hybrids; of which a detailed account is given at the end of this chapter. Certain plants do not thrive so near to London, such as violets, *Gentiana verna*, *Gentiana acaulis*. Some years ago I went to Kew to ascertain wherein our treatment of the

Gentiana was wanting: and I was pleased to find there large patches in full bloom—perfectly lovely.

I called on the Curator to congratulate him on his success, and to ask for suggestions. He replied: "Yes, they are lovely, but we do not succeed in flowering them; we purchase them in boxes which we buy in the country in full bloom. You are not the first to compliment us on our great success."

I remember, many years ago, visiting Smith's well-known Nursery at Newry with the object of obtaining a variety of heaths. Two ladies, strangers to me, accompanied us round the nurseries with the owner, and after seeing the very fine and large collection of heathers and ericas, one said to Mr. Smith, "But how do you make them grow so well?" His reply is worth remembering: "Madame, if you wish to succeed in growing plants—you must *love* them."

One of the features of our small garden is an equally small rose house, the idea of which I adopted from the garden of the late Mr. Marshall Bulley, who lived at that time near Hoylake on the Cheshire coast, one of the windiest parts of England. The gales there are of such severity that nearly all rose trees are blown out by the roots. He introduced a span roof-house fitted with glass lights, all of which can easily be removed, and replaced when required. I remember Mr. Bulley coming into Liverpool to business with a magnificent rose every morning in his buttonhole. It was this which induced me to speak to him, and thus lay the foundations of a life-long acquaintance.

The movable lights are entirely taken off about July 1, and are not replaced until the following February. The object of this is to expose the rose trees which cover the area of the house to all the winter frosts and gales, which alone can compel the plants to go to rest. Were this not done, the roses would be continually throwing out leaves and shoots instead of reserving their strength for next year's galaxy of blooms.

It takes about a month gradually to close the ventilators: after this no ventilation is given except such as finds its way in through chinks and crannies.

No artificial heat is used; the roses depend entirely on the heat of the sun. During March the young shoots push forward, and by the middle of April the finest exhibition blooms are gathered in great abundance, entirely free from pests of any description, and the foliage is clean and in splendidly perfect shape and condition.

On July 1 the glass is again entirely removed, and the plants furnish masses—I may almost say barrow loads—of bloom up to November.

I was anxious to get the *Lapageria alba*, as well as *L. rosea*, to perfection. We succeeded in doing this by observing that this plant needed the early actinic rays of the morning sun. We built a suitable conservatory facing due east, and so placed that all the sun is excluded after 1 p.m. by the dwelling house, and the plants are in the cool shade for the rest of the day. We counted on some occasions as many as 750 of these beautiful long red and white bells 4 in. in length, and we have cut at times bunches carrying as many as twenty-five to twenty-eight blooms on one stalk. In one particular year on two plants, we recorded 7,000 blooms. These plants are two of the finest grown in England.

The question of water supply to glass-houses is of great importance; the water should be soft, and its temperature should be the same as that of the house it is feeding. Therefore, a separate tank open to the air of the house is provided, the overflow from which is stored in four underground tanks. From these, in times of drought, an excellent supply of rain water can be pumped up whenever required.

It would be tedious if I were to enumerate the large number of plants in our garden, or in its houses, but there is (or rather was, for we have now lost it) one plant called *Hillebrandia sandwicensis* or Hawaiian begonia which roused much interest. We sent roots of it to Kew Botanical Gardens, to the Chelsea Physic Garden, and the Royal Botanical Gardens in Edinburgh, and also to Cambridge. It was brought to England by my son-in-law, Mr. Clive Davies, of Honolulu and Hampshire.

In consequence of the geographical position of the Sandwich Islands, in the middle of the Pacific, the distance to the nearest land is too far for the pollen of plants to traverse, consequently much of the vegetation is *mono-specific*. In this particular plant the ovaries are reversed, and it is for this reason of great interest to botanists and biologists.

Our house and garden are situated at an altitude of 160 ft. above sea-level, and command fine views of the Surrey Hills extending from the Hog's Back on the west, by the Leatherhead Valley, Leith Hill (twenty-one miles distant), Epsom, Banstead on the south, to Croydon, Addington, and Sydenham on the east.

When these houses were originally built, the Downs were real downs, with nothing on them but grass, heather, and gorse. The gardens of each were well planted with beautiful flowering trees and shrubs, but unfortunately mingled with forest trees.

The intention was that these latter should give protection to the former, until they were well established, and in five or six years to remove those of hardy and rapid growth. But this was never done, with the result that Wimbledon in places is now overgrown with forest trees, which have not only killed the ornamental plants, but have also blocked the entire view, to the great detriment of all the gardens and their owners.

My warm thanks are due to our immediate neighbours, who very considerately allow their trees to be kept down, and thinned out. Speaking to one of these friends, I said that, were it not for their kindness, we should lose our view, and that this would drive us from Wimbledon. Without a moment's hesitation he replied, "Then we will cut down all our trees!"

If all residents were as neighbourly and considerate as this, what a happy place a suburb would be!

There are various objects of interest in the garden commemorative of by-gone years. Amongst them are: a masonry key-stone from an arch of Old London Bridge, built in A.D. 1176; timber from the Norman foundations of Winchester Cathedral (A.D. 1079) and from the early English raft under the Presbytery (A.D. 1202); portions of timber from the Norman North-West Tower of Lincoln Cathedral, built in A.D. 1071; and timber from Holy Trinity Church, Hull (A.D. 1300). There are also two piles from the Bank of England in Lothbury, which was built about the year 1784, and which we had to underpin when the tube railway to Finsbury Park was made.

"Gladiolus Primulinus"

About the year 1902 I received four corms, about the size of crocus bulbs, from Mr. S. F. Townsend, of Buluwayo, the Resident Engineer of the Cape and Cairo Railway, which had reached the River Zambesi—at the Victoria Falls.

The only information we had concerning this plant was that it grew and flourished in the perpetual rain which fell from a great height thrown up by the mighty falls of the Zambesi, and also that it came from the heat of the Tropics. I therefore requested my gardener to give these corms both a wet and hot treatment and await the result.

On December 1, 1903, I sent the first bloom to Sir W. T. Thiselton-Dyer, K.C.M.G., F.R.S., the Director of the Royal Botanical Gardens at Kew, to be examined. It consisted of a single bloom with a few leaves, similar to those of an iris, standing about 12 to 16 in. from the ground ; the flower was a " self " of rich butter-yellow colour, and had five petals, the centre one of which was bent down over the pistil and stamens like an umbrella which protects the pollen from the incessant rain.

Sir William Thiselton-Dyer wrote to me on December 1, 1903, from the Royal Gardens, Kew :

" Your beautiful specimens arrived in perfect condition, and gave us all much pleasure. . . . We cannot say whether it is absolutely new to Science. It is a Gladiolus of a type which is rather widely spread in Tropical Africa—and comes, apparently, very close to one named *Gladiolus primulinus*.

" But from a horticultural point of view it seems to me quite unique, and a brilliant discovery. It ought to be the starting-point of a new race of garden Gladiolus.

" I must congratulate you on the brilliant success of your cultural treatment, which could not have been surpassed here."

These flowers, which we had named " Maid of the Mist," were exhibited at the Royal Horticultural Society's Show on August 23, 1904, and attracted much attention.

The uncertainty as to whether the plant would stand the English climate has been answered in the affirmative, and for the last twenty years we have grown and propagated it, both from corms and from seed which it produces in large quantities. Another uncertainty was, whether it would retain the "depressed" central petal, which is a very pleasing feature of the flower. We crossed it with the various Gladioli already common in English gardens, with most satisfactory results. The yellow colour and the "depressed" petal are preserved, and the vigour and growth of the English parent enable it to attain a height in some cases of even 7 to 8 ft.

We sent seeds and corms to our friends not only in England, but in Canada, United States, France, Belgium, and Holland, who also hybridised it. The result is that the blooms are to be seen in most gardens, and even on the street barrows. They have been produced in almost every colour of the rainbow, and are most attractive for table decorations, especially under an electric lamp.

This certainly fulfils the anticipation of Sir W. Thiselton-Dyer, quoted above in his letter.

Mr. Townsend wrote to me recently, November 1923: "I never dreamt of such results, though I remember thinking that 'lilies' that grew in everlasting rain must be something quite out of the common, and so dug them up whilst other members of the party collected maidenhair and slips from shrubs."

Mr. Townsend was wet through in securing these roots.

CHAPTER XXIX

SCIENCE

THE seed of scientific curiosity was, I think, originally sown in my mind by the Great Exhibition, 1851. I was fascinated by the wonderful exhibits, and my dawning interest in the nature of things was powerfully stimulated by the teaching of our dear and valued friend Professor Faraday. His lectures on the "Chemistry of the Candle," and similar subjects, still remain fresh and vivid in my memory. Following the lead thus given to me as a child, I placed myself under Professor Tyndall and other eminent scientists during the early part of my career.

Very naturally I learned to take a keen interest in all the discoveries and inventions of the day. But I shall only refer in passing to one great landmark in the history of intercommunication—the connection of the Old and the New Worlds by cable. The first submarine cable had recently been laid between England and France. My brother Douglas was on board H.M.S. *Agamemnon* when this vessel and the *Great Eastern* assisted at a later date in the laying of the first Atlantic cable. What a bold undertaking that was! Had it not been for Cyrus Field and his indomitable courage when things were at their blackest, it could scarcely have succeeded. The City of

Boston had flags flying emblazoned with the words "Cyrus Field is ours, but immortality claims him."

Many years later, in May 1900, I was invited by the President and Council of the Royal Institution to give one of the Friday-evening lectures in Albemarle Street, the late Duke of Northumberland being in the chair. The subject of my lecture was "The Simplon and other great Alpine Tunnels." I could not but deeply feel the responsibility, no less than the honour of lecturing from the spot occupied in former years by Faraday, Tyndall, Huxley, Kelvin, Rayleigh, Dewar, and many other men of great attainments. I was somewhat interested when my lecture was selected by the Smithsonian Institute of America for publication in their annual volume which is printed at the Government Office in Washington. This Society makes a practice of culling from all the publications and lectures of the entire world during each year such literary matter as "can be understanded of the people." I was glad to have an opportunity of presenting to my Washington friends copies of my various lectures and books; in return they kindly placed my name amongst the regular recipients of their interesting annual volume.

In May 1904 I was asked by the Royal Society to deliver a lecture at Burlington House on "Engineering Difficulties and the Manner in which they were Overcome." Amongst these, I selected for explanation the problem created by unforeseen pressures of grain in silo granaries. Several granaries having burst and collapsed in consequence of the pressure, I illustrated my remarks by means of a fine model. At the same lecture I showed transparent stereoscopic views of the interior of the Simplon Tunnel, then under construction, which Lord Kelvin was kind enough to describe as one of the most attractive exhibits in the Lecture-room.

On May 7, 1908, the late Lord Rayleigh, President of the Royal Society, asked me to call upon him at Burlington House, and afterwards invited me to remain and hear one or two papers read.

I sat down at the back of the room and heard Sir William Crookes giving a demonstration of some rare metals. He handed up to Lord Rayleigh a small spoon about the size of a sixpence, made of that very rare metal rhodium, worth seven times the value of gold, which had been made for him by Messrs. Johnson & Matthey. Its particular use lay in its resistance to heat and the strongest of acids. Much interest was displayed by the meeting, and after some remarks of his own, the President invited anyone who wished to do so, to speak. There was, however, no response, for very few probably had ever seen rhodium before. I had had no intention at all of speaking, and indeed I had no *locus standi* at the meeting. But, as no one else spoke, I stood up and said : " My Lord, I have listened with great interest to Sir William Crookes in his description of this very rare, but useful metal, for, as a matter of historical interest, I have in my possession an ounce of that metal extracted by Dr. Wollaston, its discoverer, and given by him to Dr. Ure.

This celebrated scientist's chemical balance was presented to me, some forty years ago, by his daughter Mrs. Mackinlay, and I found a little parcel hidden away in the drawer of the balance, on which was written in faded pencil, 'Rhodium from Dr. Wollaston.'"

My remarks were received with attention, and at the conclusion of the meeting, Sir William Ramsay spoke to me, and said that they were all much interested in what I had told them. But the incident did not end there, for Dr. S. Monckton Copeman, F.R.S., came up to me and said: "What an extraordinary coincidence! First that you should, by mere chance, have attended the lecture when rhodium was described, and secondly that I, a relative of Dr. Ure, should be present. It has always been a matter of wonder to me what had become of Dr. Ure's chemical balance." After hearing that, I could not do less than make a present of the balance to Dr. Copeman; whereupon—yet another coincidence—his wife kindly gave me a miniature which she possessed of my grandmother, Mrs. Francis Fox, of Derby.

In May 1911, at the request of Sir William Crookes, I exhibited at the soirée of the Royal Society some pitchblende which we had mined in Cornwall, and from which Sir William Ramsay had extracted the radium. The value of this quantity of 300 mgms., worth £20 per mgm., was £6,000, the largest quantity of radium ever seen in London up to that date.

A number of scientific friends kindly proposed me for election to the Royal Society, but I shared the common fate of so many candidates—I was not elected. I was, however, proposed a second time—and a second time I failed. A few days later I heard that when fourteen Fellows (fifteen being the full number for the whole world) had been selected, another candidate and myself were in the balance. To use the language of metaphor, they "tossed up" for the fifteenth. The honour fell to my companion, and I was again out of it. Though he was a stranger to me, he sent me the kindest of letters in which he expressed his regret that he had unfortunately been the cause of my failure. I replied that if anything were needed to justify his election, his letter was evident proof that the Council had chosen the right man. Sir William Crookes, who was at that time President, urged me to allow myself to be nominated once more, but this I felt obliged to decline.

May I, by the way, on this subject of election to the Royal Society, express an opinion which I know to be shared by many? Is it desirable, that in a single election one English University should be allowed the large number of nine vacancies? Science is faithfully served in other parts of the world.

CHAPTER XXX

CONCLUSION

I HAVE now given an abbreviated description of some of the varied phases of work which during our long and united professional life my brother and I have carried out both above and under ground: as also above and under water. I have left out most of the technical details in order that the book may be readable by everyone.

I have also naturally omitted many of the social details of my life as being too personal, but as for the last sixty years I felt very strongly the duty of living in close touch with one's neighbours, particularly those in the poorer districts, I have endeavoured to interest my readers who perhaps have never seen real poverty either in their lives or in their surroundings.

I have frequently been asked the question by many most kindly disposed people, "But what can I *do* in so-called social work to assist the poor?" and this I have endeavoured to answer to some extent.

In looking back upon my long life and my years of strenuous and hard work, I often wonder as to what it is that I can attribute any measure of success to which I may have attained.

I was brought up by my parents to regard work as one of God's most precious, and therefore one of His noblest, gifts. I determined to work my hardest, and not to be led astray in regarding work as something to be deprecated and avoided. "Duty first, pleasure afterwards" is a golden rule with which all should endeavour to comply: but to-day games and theatres, cards, dancing, motoring, are regarded by vast numbers of people as the chief objects to pursue, and have degenerated into complete obsession: work is only to be regarded as a dire necessity for earning one's livelihood, and this has resulted in grievous idleness, thus destroying one of the greatest and best impulses of life. One of my most valued friends, a well-known schoolmaster, asked one of his pupils, whose father was the President of a leading bank in London, for what branch of work he desired to be trained, and the innocent answer was made "a retired Banker."

"If a man will not work neither shall he eat," and Christ Himself worked at the Carpenter's bench, thus ennobling that trade for ever.

The Prince of Wales' motto "Ich Dien," "I serve," should be engraved on everyone's mind.

The question is, amidst the very dangerous enterprises in which I have been engaged, and in which I have never met with any accident of moment, how can I account for my immunity when so many others have been maimed and even killed? I will endeavour to answer this as briefly as I can, and will add a few words to the young men and young women of to-day.

Seventy years ago I was at a school near Nottingham, kept by a kind and excellent clergyman, and we went on Sunday to a small church at Carrington, near Mappleby, and attended the ministration of the Rev. D. Whalley of the Established Church. He preached plain simple sermons which appealed strongly to us as boys. One particular Sunday morning he gave us in boyish language a very vivid picture of Christ during His ministry of three years, and one could almost see the figure of the Saviour.

The point that the preacher emphasised was that everyone should endeavour "to realise the continual presence of Christ," and I resolved that I would set my face to do this, beginning each day with a prayer to God for His guidance, and control, in every detail, whether domestic, business, or official.

It has been a complete protection to me all these long years and the words of the Proverbs, "In all thy ways acknowledge Him, and He shall direct thy paths," have proved correct.

I was in great danger at sea, in the heaviest of Atlantic gales, with the temperature at zero, the ship covered in ice 3 ft. in thickness with all the boats frozen in blocks of ice to the deck.

On another occasion in the midst of the Simplon Tunnel with 7,005 ft. of rock and soil above our heads, the earth pressure was so great, that the advance heading was crushed in, the timbering destroyed, and the rock moving. Colonel Locher and I had to climb or crawl for a distance of 80 yards to ascertain the cause, and I know that he for one, and myself for another, hardly expected to get out alive.

In the Island of Capri we encountered rocks falling from a height above us of 2,000 ft., the fragments falling all around us; and in the Apennines when exploring for minerals a large boulder bounded down the mountain, striking our interpreter, fracturing his skull, but we were mercifully preserved.

In diving under water I again had dangerous experience, as was the case on the mud-banks of the Solent (as published elsewhere); our surveying party of eight were all bogged a mile from shore in the mud, up to their waists, and one up to his neck: we should all have been lost had I not providentially been able to extricate my mud pattens, and then by rolling over and over on the surface of the mud I reached some green weed, from which I was able to get to the boats and summon assistance.

Besides all these—in times of sorrow, in occasions of sickness, of fiery temptation of all kinds, by the grace of God I have been preserved: "His Grace was sufficient for me."

The late Sir David Gill, F.R.S., Astronomer of the Royal Cape Observatory, whom I had the pleasure of knowing intimately, was evidently of the same opinion, as he once wrote to me as follows: "The simplest rule in all life is to ask oneself what Christ would have done in the circumstances, and then try to do what you honestly believe He would have done."

This coming as it did from one of our leading scientists should carry great weight.

I desire to refer to a subject of the greatest importance, which is very conducive to the happiness and good feeling amongst the members of a household.

The regular observance of Family Prayers, accompanied by a morning hymn, constitutes a bond of kindly feeling and brotherhood throughout one's home; and for those who desire printed prayers, arranged for almost every possible event, I find a small book entitled *A Chain of Prayer Across the Ages: Forty Centuries of Prayer* most helpful.

In the New Testament we are enjoined, "If any man lack wisdom let him ask of God, Who giveth to all men liberally and upbraideth not."

We all frequently lack wisdom, and were such an offer made to us, and we declined to accept it, we should only and rightly be written down as fools.

Now my book has reached its end.

During the sixty-three years, I have engineered the construction of railways, tunnels, buildings of all kinds: sea works: development of mines. But I look forward to construction of very different character, "An house not made with hands, Eternal in the heavens."

"Thanks be unto God for His unspeakable Gift."

And when we ask what is the nature of that Gift, we find the answer: "The Gift of God is Eternal Life through Jesus Christ our Lord."

I end with the quotation which was my dear Brother Douglas' favourite text: "Jesus Christ, the same yesterday, to-day, and FOR EVER."

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